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भारतीय मानक

टेरोटेक्नोलॉजी (परिसम्पतियों का आर्थिक प्रबंध) की मार्गदर्शिका

भाग 3 उपलब्ध तकनीकों की मार्गदर्शिका

Indian Standard

GUIDE TO TEROTECHNOLOGY (THE ECONOMIC MANAGEMENT OF ASSETS)

PART 3 GUIDE TO THE AVAILABLE TECHNIQUES

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FOREWORD

This Indian Standard (Part 3) was adopted by the Bureau of Indian Standards, after the draft finalized by the Management and Productivity Sectional Committee had been approved by the Management and Systems Division Council.

In any organization, it is necessary to identify and then choose between the investment options open to it and to make decisions on how best to invest the capital available. Once a decision has been made to make an investment in some form of physical asset or project, then the application of terotechnology should assist in the object of getting the best value for money from that investment and thus justify it.

Terotechnology is a combination of management, financial, engineering, building and other practices applied to physical assets in pursuit of economic life cycle costs. It is concerned with the specification and design for reliability and maintainability of physical assets such as plant, machinery, equipment, buildings and structures. The application of terotechnology also takes into account the processes of installation, commissioning, operation, maintenance, modification and replacement. Decisions are influenced by feedback of information on design, performance and costs, throughout the life cycle of a project. It applies equally to both assets and products because the product of one organization often becomes the asset of another. Even if the product is a simple consumer item its design and customer appeal will benefit from terotechnology and this will reflect in improved market security for the producer.

Terotechnology was developed in the context of larger organizations, with the objective of making them more efficient and competitive. Throughout this standard the applicability to a larger organization is used as a basis as this will represent the more complex situations. However the objective of maximizing value for money spent and the principles involved in achieving this, are equally applicable to small organizations. Small organizations face problems as much as those faced by the larger; more complex organizations. Their problems may be simpler but the principles of problem solving remain the same. The small organization can therefore benefit from this guidance by selecting those parts of the decision-making process that can help them.

Regardless of the success (or failure) achieved in the management of an asset, the experience can provide valuable feedback which is fundamental requirement of terotechnology. This feedback is gathered by monitoring decisions, actions, consequences and the lifetime performance of the asset and can be used to improve confidence in new decisions.

The cyclic nature of terotechnology demands that decisions about asset management are reviewed in the light of increasing experience and knowledge. Throughout an asset's life, relevant data need to be collected and analyzed to guide current management decisions and the consequences of resulting actions recorded, providing feedback to guide new decisions. This structured, analytical approach results in better decision-making throughout the organization, thereby providing opportunities to improve profitability and/or efficiency.

This standard sets out in detail all the activities that should be carried out to ensure that the organization, which uses terotechnology, could compete successfully and at the same time, achieve consumer satisfaction.

As explained in IS 15363 (Part 1) and IS 15363 (Part 2), many organizations can act both as user and supplier. Furthermore, it is clear that one person's product can become another's asset. To avoid confusion, this standard is written from the viewpoint of a user organization seeking and then using an asset to produce its own product. The need for a supplier to give maximum consideration to his customers' terotechnology needs in designing his products, as well as his own similar needs in acquiring and using parties if they adopt terotechnology principles.

This standard is largely based on BS 3843 (Part 3) : 1992 'Guide to terotechnology Part 3: Guide to the available techniques'. The Committee decided not to include technique 54 'Recruitment' and technique 65 'Technical Diagnosis and Analysis' in this standard.

This standard is published in three parts. The other parts in the series are:

(Part 1) : 2003	Introduction to terotechnology
(Part 2) : 2003	Introduction to techniques and applications.

Indian Standard

GUIDE TO TEROTECHNOLOGY (THE ECONOMIC MANAGEMENT OF ASSETS)

PART 3 GUIDE TO THE AVAILABLE TECHNIQUES

SECTION 1 GENERAL

1 SCOPE

This standard (Part 3) gives detailed guidance to implement terotechnology practices in the work. The standard also consists of series of checklists intended for use by persons responsible for a specific function in an organization.

2 REFERENCES

The standards listed in Annex A contain provisions which, through reference in the text, constitute provision of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed in Annex A.

3 TERMINOLOGY

For the purpose of this standard definitions given in IS 9990 together with the following shall apply.

3.1 Terotechnology — A combination of management, financial, engineering, building and other practices applied to physical assets in pursuit of economic life cycle costs.

NOTES

1 Terotechnology is concerned with the specification and design for reliability and maintainability of physical assets such as plant, machinery, equipment, buildings and structures. The application of terotechnology also takes into account the processes of installation, commissioning, operation, maintenance, modification and replacement. Decisions are influenced by feedback of information on design, performance and costs, throughout the life cycle of a project.

2 Terotechnology applies equally to both assets and products because the product of one organization often becomes the asset of another. Even if the product is a simple consumer item its design and customer appeal will benefit from terotechnology and this will reflect in improved market security for the producer.

3.2 Board — Superior management level of the organization, ultimately responsible for deciding upon and authorizing any new project, specifying the objectives and policies to be followed in assessing options.

3.3 Organization — The totality of the enterprise which is to undertake a proposed new or additional project.

NOTE — This may be a large industrial company, a public service or in the extreme an individual.

3.4 Spare — A replica or equivalent component purchased to replace the original component supplied as part of the asset.

NOTE — Replacement is normally expected to be required due to failure in its widest sense.

3.5 Technique — An identifiable mathematical or logical procedure or procedures or a subject area which is or has been studied analytically by experts.

3.6 Supplier Rating — Assessment of a supplier's ability to fulfil promises of performance, quality, cost and delivery.

NOTE — In most cases this is made by the intending purchaser's Quality department or engineer, using past experience and other relevant information.

SECTION 2 GUIDANCE TO THE TECHNIQUES

4 LIFE CYCLE OF A PROJECT

4.1 Within the context of this standard a project is deemed to commence with the establishment of an organizational objective that calls for the acquisition of an asset with which to produce a product. The represents the asset's and the project's life cycle.

4.2 For any life cycle there will be four distinct phases. These are:

a) *First phase — Concept/investment decision phase*

In this objective is translated into the identification and, in some cases, the choice of a product and hence the asset required to produce it.

b) *Second phase — Acquisition phase*

In this phase, the asset is acquired and put to work.

c) *Third phase — Useful life phase*

This is sometimes termed as Operation and Maintenance phase.

d) *Fourth Phase — Disposal phase*

Finally when the asset is no longer required to produce, or capable of producing, the product, it has to be disposed of. This activity can involve further costs against the project but may also attract savings. Thus the disposal phase will involve further activities which should be organized to achieve the best terotechnological advantages for the organization.

These four phases will be applicable to all projects, but may overlap to some extent.

4.3 Within each phase the activities may be divided into a number of separate stages. These are shown in Table 1 in chronological order. For a particular project the order of these stages may be changed by the particular circumstances; their relative importance and formality can also be markedly different from project to project.

5 LIFE CYCLE BREAKDOWN OF TECHNIQUE

5.1 IS 15363 (Part 2) discusses the application of techniques in the terotechnological management of a project during the four phases identified in **4.1**, with the activities in the Useful Life phase split between the production and maintenance areas. Table 2 summarizes which techniques are applicable in which phase and to which activities.

5.2 Because terotechnology is concerned with the economic management of a project, economic appraisal of alternative possible courses of action arises whenever such alternatives are encountered. In practice, these can arise in any phase and any stage, and thus the basic techniques used in such economic analyses are applicable throughout the project. Consequently, these are identified separately and ahead of those listed under the various Phases.

6 LAYOUT OF GUIDANCE SHEETS FOR THE TECHNIQUES

6.1 Each of the techniques identified in Table 2 is provided with a guidance sheet to follow in 7. The layout of each sheet is based on the format shown in Table 3. Whilst some techniques will be well known such that little guidance is needed, others are relatively new or are still being developed. Because of this, guidance to known sources of details of such techniques is more appropriate in this standard than an attempt to give a comprehensive account of the details. Furthermore, some techniques require extensive guidance to the extent that a full description would require a complete and separate standard or a complete chapter of a textbook.

6.2 Each guidance sheet is numbered and cross-referenced against the relevant phase(s) and stage(s) listed in Table 2.

Table 1 Phases and Stages of a Project

(*Clause* 4.3)

Sl No. (1)	Phases (2)	Stages (3)
i)	1) Concept/Investment Decision	Identification of objectives Identification of possible project proposals Initial research of options, leading to estimated cash flows and risk assessments Identification of constraints on organization, leading to judgement criteria Selection of option(s) to be pursued
	2) Acquisition	User lists requirements/specifications User identifies potential suppliers Supplier consider enquiry, identify outline designs for offer and response Suppliers' offers and supporting data submitted in tenders User considers tenders and selects a supplier after negotiating mutually acceptable contract terms Selected supplier carries out or selects detailed design and plans programme Acquisition of materials Manufacture and testing (including quality assurance) Delivery Construction/Erection/Installation Commissioning including testing and proving Recruitment and training of user's staff
ii)	Useful Life (Operation, maintenance)	Production and operation Maintenance, including modifications Collect data for optimization of this project and/or for use in future project selections Periodic reviews of project until a final review leads to decision to terminate this project
iii)	Disposal	Identification of methods in light of constraints Evaluate options and select best Dispose

Table 2 Life Cycle Breakdown of Techniques

(*Clause* 5.1)

Sl No. (1)	Phases and Stages (2)	Name of Technique (3)	Technique Number (4)
i)	General Economic Appraisals	Discounted cash flow	1
		Net present value	2
		Internal rate of return	3
		Annuity	4
		Rate of return	5
		Payback	6
	Cost-benefit analysis	7	
ii)	Concept/Investment Decision Phase		
	1) Identification of options	Market research	8
	2) Detailed study and evaluation of options	Product design review/audit	9
		Project design appraisal	10
	3) Risk and uncertainty	Probability analysis	11
		Risk analysis	12
iii)	Acquisition phase		
	1) Technical requirements for specification	Product design review/audit	9
		Drawings	13
		Queuing theory	14
		Value engineering	15
		Reliability/maintainability analysis	16
		Plant history files	17
		Supplier assessment	18
		Performance analysis	19
		Ergonomics	20
		Environmental planning	21
		Flow charts	22
		Control of waste	23
	2) Assessment of tenders	Project design appraisal	10
		Construction analysis	24
		Modelling	25
	3) Manufacture	Design schedules	26
		Drawings	13
		Quality programme	27
		Quality assurance methods	28
		Test procedures	29
		Financial analysis and budgets	30
	4) Erect/install	Network analysis	31
		Bar charts	32
		Progress assessment	33
		Safety consultation	34
		Technical manuals	35
		Expected cost to completion	36
		Handling and storage	37
		Structural safety limits	38
	5) Commissioning	Network analysis	31
		Quality programme	27
		Drawings	13
		Technical manuals	35
		Commissioning procedures	39
		Training schedule	40
		Performance guarantees	41
iv)	1) Useful Life phase. Operational aspects		
	a) Production management	Order processing	42
		Technical manuals	35
		Plant history files	17
		Allowance for statutory inspections	43
		Operator maintenance	44
		Life assessment	45
		Operator instructions	46

Table 2 (*Concluded*)

Sl No. (1)	Phases and Stages (2)	Name of Technique (3)	Technique Number (4)
	b) Output performance	Material needs	47
		Work study	48
		Stock control	49
		Data logging	50
		Control limits	51
	c) Resource optimization	Operational research	52
		Production planning and control	53
		Employee training	55
		Energy management	56
		Quality assurance methods	28
		Marketing programme	57
	d) Feedback to new projects	Data logging	50
		Reports	58
		Plant history files	17
	2) Useful life phase. Maintenance aspects		
	a) Maintenance management	Quality records	59
		Asset inventory	60
		Technical manuals	35
		Drawings	13
		Work instructions	61
		Reports of work done	62
		Allowance for statutory inspections	43
		Maintenance scheduling	63
		Resource allocation and planning	64
		Reliability/maintainability analysis	16
		Design appraisal (project)	10
		Failure investigations	66
		Fault analysis	67
		Tribology	68
		Stock control	49
		Work study	48
		Employee training	55
	b) Health of asset	Maintenance history and analysis	69
		Repair/replacement optimization	70
v)	Disposal phase	Risk analysis	12
		Plant history files	17
		Flow charts	22
		Construction analysis	24
		Safety consultation	34
		Technical manuals	35

7 GUIDANCE SHEETS FOR THE TECHNIQUES

NOTE — Guidance sheets for techniques 1 to 70 are given in 7.1 to 7.68, respectively.

7.1 Technique 1— Discounted Cash Flow (DCF) [*see* Table 2, Phase (ii)]

7.1.1 *Basic Principles of Technique*

7.1.1.1 A sum of money available in the present will, by investing it at a fixed interest rate, grow to a larger sum, measured in money terms, in future years. From this it follows that a sum of money accruing in the future is equivalent to a smaller sum of money in present-day terms. Thus, when a payment of Rs. X, has to be made in the future, a sum of Rs. Y, which is smaller than Rs.X, can be invested today at an interest rate of *r* which will yield the sum of Rs. X at the future point in time at which it is required for payment. The sum Rs. Y is termed the 'present worth' of the sum Rs. X and it is obtained by discounting Rs. X at a discounted rate r. Because of this time value of money, it is not possible to compare directly sums of money accruing at different times in the future. To make such a comparison possible it is necessary to convert these sums to their equivalents at a common point in time, by discounting. The process involved in discounting is in fact the inverse of compounding. In order to assess two different investment proposals, each involving a number of cash flows at different points in the future, the proposals can only be compared after all cash flows have been discounted to a common base date at a common discount rate which is appropriate to the circumstances and agreed by all parties involved. The common base date does not necessarily have to be the

Table 3 Layout and Explanation of Guidance Sheets for the Techniques

(*Clause* 6.1)

Sl No. (1)	Guidance Sheet Sections and Sub-sections (2)	Purpose (3)
i)	Technique	To give the title of the technique and any alternative title(s)
ii)	Basic principles of technique	To give the purposes of the technique in general terms
iii)	Usage in terotechnology	To indicate when and where the technique is used in terotechnology, including in which Phases of a project
iv)	Details of technique and applications	To cover how the technique is carried out (usually in general terms) and how it is applied in circumstances given in Section 3 of the guidance sheet. The full intent of this section is normally covered in the subsections detailed below. However, in some cases an introductory paragraph has been included to aid readability of the section
	Sub-sections	
	a) References	To give references to more detailed descriptions of the technique
	b) Related techniques	To indicate other techniques used in applying the technique in question. This sub-section has been omitted if the technique is in effect a basic technique
	c) Further information	To give additional, detailed information on the technique. This sub-section has been omitted where the technique is adequately covered in the references given in iv)(a).
	d) Examples	To give examples of situations where the technique is applicable. This sub-section has been omitted where the technique is adequately covered in the references given in iv)(a)

present time, but could be some date in the future, such as the start date for the proposed project.

7.1.1.2 The discounting of cash flows is more than just a technique. It is a principle that is involved in all modern methods of investment appraisal. Unfortunately, the term 'Disconted Cash Flow' is also used to denote a specific method of investment appraisal in which the discount rate is calculated which, operating over the life of a project, gives a zero net present worth of all the cash flows associated with the project. To avoid confusion the alternative name 'Internal Rate of Return' for this investment appraisal method is preferred. (*see* Technique 3.) The DCF principle is also used in Technique 2 (Net Present Value) and Technique 4 (Annuity).

7.1.2 *Usage in Terotechnology*

The DCF technique/principle is used in all economic appraisals in which expenditures and incomes occur at different points in time. It is especially used in the concept/investment decision phase where investment in an asset at the start of a project has to be viewed in conjunction with or in comparison with the operational costs and revenue or savings arising throughout the commissioned life of the asset concerned. When applying DCF, the cash flows taken into account should always be with due allowance of the timing of tax payments and tax allowances.

7.2 Technique 2 — Net Present Value (NPV) [*see* Table 2, Phase (i)]

7.2.1 *Basic Principle of Technique*

This technique is used to evaluate the relative merits of alternative proposals for investment in assets to meet a given objective. Essentially the technique is only applied to projects which have a financial return and are economically viable. To enable comparison of widely different assets, results are usually expressed in terms of net cost per unit of capacity or out put where options can be measured in this way. In this technique, the commonest form of DCF, discounting is carried out at a predetermined discount rate. It is, therefore, particularly suitable where constant rates of interest are applicable or are expected throughout the life of the project.

7.2.2 *Usage in Terotechnology*

7.2.2.1 The technique is first used in the conceptual phase of a new project to determine which of alternative asset acquisitions should be studied in greater depth.

7.2.2.2 During the life time of an existing asset the technique may also be used to compare alternative options such as extending planned life of an existing asset or scrapping and replacing it.

NOTE — The Net Present Value of a proposed project is the calculated value, in present worth terms at the base date, of the expected income from the sale of output over the lifetime, less the acquisition costs and operating costs over the lifetime (including disposal).

7.2.3 *Related Techniques*

In the use of this technique all costs and returns are expressed in terms of their 'present worth' values at a base date which is usually chosen to be the proposed commissioning date of the proposed asset. (*see* Technique 1, Discounted Cash Flow).

7.3 Technique 3 — Internal Rate of Return [*see* Table 2, Phase (i)]

7.3.1 *Basic Principles of Technique*

7.3.1.1 This method is essentially the same as that described in technique 1 as the special case of the term 'Discounted Cash Flow'. The calculated Internal Rate of Return (IRR) is also known as the Discounted Cash Flow Rate of Return (DCFRR).

7.3.1.2 This technique finds the discount rate (the IRR) at which the Net Present Value (NPV) is zero. The IRR method only compares rates of interest whereas the NPV method allows comparison of sums of money and for this reason the NPV method is often preferred to the IRR method.

7.3.2 *Usage in Terotechnology*

This technique can be used in all economic appraisals in all phases.

7.3.3 *Related Techniques*

Discounted Cash Flow: Technique 1.

7.4 Technique 4 — Annuity (Annual Capital Charge) [*see* Table 2, Phase (i)]

7.4.1 *Basic Principles of Technique*

This technique offers an alternative way of presenting the value of net expenditure over a period. In essence, it presents expenditure in terms of a fixed nominal sum that would have to be paid each year over the period which has the same value as the (annually variable) expenditure expected.

7.4.2 *Usage in Terotechnology*

In terotechnology, the technique is used to present life cycle costs, covering purchasing, operating and maintaining the asset as a single nominal annual sum over the life cycle period. (In some cases the costs of disposal would also be included.) In this form it can be used to compare the life cycle costs of alternative proposals with differing life cycles, more readily than by the use of present worth presentation of the same costs. Comparisons of costs with expected returns, especially when these are expected to be reasonably constant, are also easier to make using this technique.

NOTE — The relationship between Annuity (A) and Total Present Value [$C(P)$] is given by the equation:

$$A = C(P) [(c/(1-(1 + c)^{-P}]$$

where P is the period in years and c is the calculation rate of interest.

7.4.3 *Related Techniques*

Net Present Value : Technique 2.

Discounted Cash Flow : Technique 1.

Internal Rate of Return : Technique 3.

7.5 Technique 5 — Rate of Return (RR) Return on Investment (ROI) [*see* Table 2, Phase (i)]

7.5.1 *Basic Principles of Technique*

The terms above are two of the commonest forms used for the book (or accountants') rate of return and are defined as the ratio of profit (net of accounting depreciation) to the capital.

7.5.2 *Usage in Terotechnology*

This method is not appropriate to economic appraisals but is one that is used in publishing accounts for a project. It particularly fails to allow for the incidence of capital outlays and incomes. Whilst it can be useful for comparing established processes, it is unsuitable for innovations.

7.6 Technique 6 — Payback [*see* Table 2, Phase (i)]

7.6.1 *Basic Principles of Technique*

7.6.1.1 This technique is based upon the assessment of the number of years before the cash flows from income from the project equal its capital cost.

7.6.1.2 In practice such calculations may be carried out in terms of incomes gross of tax or net of tax and the method employed should be clearly identified.

7.6.1.3 Acceptable projects are those whose payback periods are less than some predetermined time and within this constraint projects with the shortest payback periods are selected.

7.6.1.4 This method has certain disadvantages. It takes no account of cash flow after the payback point has been reached and it ignores the time distribution of the cash flows (that is, no discounting).

NOTE — Some organizations use present worth equivalents of the cash flows in their application of the technique. This variant is also referred to as the 'payback method' although strictly speaking this is not correct.

7.6.2 *Usage in Terotechnology*

This method of comparing options may be suitable for short-terms projects. It also has a place, usually in conjunction with DCF based techniques, when cash control is to be done.

7.7 Technique 7 — Cost-Benefit Analysis [*see* Table 2, Phase (i)]

7.7.1 *Basic Principles of Technique*

7.7.1.1 Techniques 1 to 6 are applicable when the output from a project, or its income, is capable of being measured or assessed in tangible cash terms. Many social projects, however, are not capable of having their outputs identified in such terms. In such cases and in others where a substantial part of the benefits cannot be assessed in terms of cash, these techniques cannot be used.

7.7.1.2 Nevertheless, economic appraisal of alternative courses of action should be carried out. Instead of profitabilities being calculated it is necessary to calculate a suitable cost-benefit index for each alternative. An index such as the cost per patient treated may be appropriate in, say a hospital scheme.

7.7.2 *Usage in Terotechnology*

This technique, using the principles of DCF, should be used to compare schemes whenever appropriate, as described above. The inability to identify scheme benefits in cash terms should not be used as an excuse for not carrying out economic appraisals of alternatives.

7.8 Technique 8 — Market Research [*see* Table 2, Phase (ii)(1)]

7.8.1 *Basic Principles of Technique*

Market research is a general term describing various techniques employed by, or on behalf of, a supplier or prospective supplier in respect of a product or proposed product. These techniques are aimed at obtaining an estimate of one or more of the following objectives:

a) Potential size of the market in terms of number of units of the product required and the time scale involved.
b) Supplier's likely share of that market.
c) Probable effect on the market of the unit price of the product.
d) Features and characteristics of the product/proposed product deemed especially important by potential customers.

7.8.2 *Usage in Terotechnology*

7.8.2.1 In terotechnology, market research is principally of value in the concept/investment decision phase, firstly to determine the capacity of the proposed asset and then in terms of limits to inputs into the economic assessment of the proposed project. During the operation and maintenance phase, further market research estimations can be used to refine studies on whether an asset should be refurbished or replaced.

7.8.2.2 The individual market research techniques to be used will depend upon the product involved but might include one or more of the following:

a) Formal or informal questionnaires either issued to the general public or to specially targeted potential customers.
b) Review of existing products and sales.
c) Review of customers' inputs or queries raised by potential customers.
d) Analysis of officially collected statistics (by government or a trade association).

7.9 Technique 9 — (Product) Design Review/Design Audit [*see* Table 2, Phase (ii)(2) and (iii)(1)]

7.9.1 *Basic Principles of Technique*

7.9.1.1 During development of a product design, it is essential that the work is monitored and controlled to ensure that the emerging design will satisfy the requirements and be within the constraints of the design brief. This brief will have incorporated in it the relevant requirements directed by the board of the organization for the project. For details refer IS/ISO 9000:2000, IS/ISO 9001:2000 and IS/ISO 9004:2000.

7.9.1.2 To ensure that these requirements are met, a formal review procedure is desirable with the design being scrutinized at specific review points. The recommended stages are:

a) Completion of the design concept;
b) Completion of the detailed design drawings; and
c) Completion of prototype testing.

7.9.1.3 Whilst a general view on the asset required for producing the product may be obtained at stage (a) (*see* **7.9.1.1**), a full specification of the asset may not be possible until the detailed design is complete, that is stage (b). Thus there is a direct interplay between the design of the product and the asset required for the project, and also on the costs of production. These are important factors in the concept/investment decision phase of the project. For comparison between options, the results of the first stage design review may be sufficient to eliminate some of these and the cost of further design work on these can be avoided. In many cases development to point (b) will be necessary for the final investment appraisal on which final authorization is sought for the project to proceed.

7.9.2 *Usage in Terotechnology*

This technique is used in the early stages of the concept/investment decision phase.

7.10 Technique 10 — (Project) Design Appraisal [*see* Table 2, Phase (ii)(2), (iii)(2) and (iv)(2)(d)]

7.10.1 *Basic Principles of Technique*

This is an appraisal of the proposed asset and its usage to furnish the proposed product. The implications of the asset design on reliability/availability and thus output and on operation and maintenance costs should also be assessed.

7.10.2 *Usage in Terotechnology*

7.10.2.1 This technique is principally used in the concept investment decision and acquisition Phases.

7.10.2.2 This technique is initially used in the concept/investment decision phase, and is applied to the first draft outline design of the asset. At this stage the appraisal is used to refine the specification for the asset, in terms of numbers and capacities of components. In the later stages of the concept/investment decision phase, design appraisal is used to identify, as accurately as possibly, all the significant cost and performance implications of the options being considered and especially the preferred option when this is identified.

7.10.2.3 The technique is also used in the early stages of the acquisition phase to identify and quantity, whenever possible differences between offers for the supply of the specified asset. Once a supplier has been selected, and especially during the commissioning stage, detailed design's appraisal has to be carried out to identify the needs for trained personnel, for production, maintenance and product support and for other resources such as repair material and spares.

7.10.2.4 During the life of the asset, the technique may also be used when replacement of a major component of the asset is being contemplated and significantly different options are available.

7.11 Technique 11 — Probability Analysis [*see* Table 2, Phase (ii)(3)]

7.11.1 *Basic Principles of Technique*

In any study or comparative study, the effects on the end result of the various parameters used in the calculations are established. When an input parameter has to be estimated it can often be of distinct value to establish the effect on the end result of variations of the parameter over its likely range and to calculate the likely result by weighting each result by the assessed probability of the corresponding input having the value to be experienced in practice.

7.11.2 *Usage in Terotechnology*

In the concept/investment decision phase, the use of probability analysis on the inputs to the economic appraisal of a prospective project may give a better estimate of likely viability than by using mean/median or best guess values for the input parameters. Such an analysis could also highlight certain risks inherent in the proposal. In the Acquisition phase the technique, similarly applied, can help in the selection between prospective suppliers of the asset.

7.12 Technique 12 — Risk Analysis [*see* Table 2, Phase (ii)(3) and (v)]

7.12.1 *Basic Principles of Technique*

7.12.1.1 This technique is used in two separate areas, namely that of analysis of the risk in committing funds to a project and, secondly, that relating to the risks in respect of safety.

7.12.1.2 Risk analysis may be applied to the commitment of funds to a project and the likelihood that those funds may be lost. It may be measured against a base where it is known that the committed funds are secure. In financial terms this base is often government gilts.

7.12.1.3 Once the risk has been assessed this may be translated into the return expected from the investment; the greater the risk the higher the return demanded. This is then often used in determining the discount rate used; again, the greater the risk the higher the percentage used.

7.12.2 *Usage in Terotechnology*

7.12.2.1 In terotechnology risk analysis relates to the identification and analysis of those risks which either threaten the assets themselves, their performance and costs or the earning capacity of the organization in terms of its output of products or services.

7.12.2.2 Risk analysis of hazards to employees, customers or the general public should be included in the assessment, and consequence of such risks in either financial terms or in terms of constraint or embargo on a proposed course of action, as appropriate, should be taken into account.

7.13 Technique 13 — Drawings [*see* Table 2, Phase (iii)(1), (iii)(3), (iii)(5) and (iv)(2)(a)]

7.13.1 *Basic Principles of Technique*

7.13.1.1 Drawings are an essential part of all technical communications between parties involved in a project. These communications take place within the supplier's organization, within the user's organization and also between the supplier and the user. Whilst few drawings can convey ideas without a supplementary text, they will often convey ideas more clearly and permit explanation of an idea with a minimum of accompanying text.

7.13.1.2 In most technical disciplines there are conventions and rules which are applied to drawings and these should always be followed to avoid confusion or misunderstanding.

7.13.2 *Usage in Terotechnology*

7.13.2.1 Communication between parties and therefore use of drawings associated with these communications takes place in all phases of a project.

7.13.2.2 In the concept/investment decision phase these drawings are principally used within the user organization during the formulation of the project. In the acquisition phase, the principal drawings are produced by the supplier and submitted to the user. Initially these will relate to the offer being made. In the case of a large unique project these will progress from those giving outline designs to drawings in more developed detail. Towards the end of the Acquisition phase, drawings should be submitted to the user which show the asset in some detail in the form in which it is actually being supplied. At this time the supplier should also supply such drawings as are necessary for training of and use by the operators and those needed to assist in the maintenance of the asset. Special drawings needed for the erection of the asset and/or dismantling and disposal of the asset at the end of its life should also be provided. Drawings necessary for training of and use by operators, and drawings needed for the erection and/or dismantling of the asset should be included in the technical manual (*see* Technique 35).

7.14 Technique 14 — Queueing Theory [*see* Table 2, Phase (iii)(1)]

7.14.1 *Basic Principles of Technique*

7.14.1.1 This technique relates to the use of mathematical models and theorems in the analysis of systems of finite capacity in which service is to provided under conditions of varying supply and demand.

7.14.1.2 Queueing is an activity with which everybody is familiar and it applies to machines, money and materials, as well as people. Queueing theory is based on statistical principles and is frequently used to solve management orientated problems. In general, it has applications to those types of problem where a varying demand has to be accommodated by a discrete number of service units.

7.14.1.3 In the maintenance field the sizing of work forces is a particular area where queueing theory can be of benefit.

7.14.2 *Usage in Terotechnology*

In terotechnology this technique is first used in the design of the asset and how it is to be operated. This is particularly appropriate in those cases where the product is produced in a series of stages and also where a stage involves batch processing. The analysis can also be applied to the flow of materials.

The method is also applicable in the management of maintenance of the asset, both in terms of task allocation and in the supply of spares and material.

7.15 Technique 15 — Value Engineering [*see* Table 2, Phase (iii)(1)]

7.15.1 *Basic Principles of Technique*

7.15.1.1 Value Engineering (VE) is a discipline comprising a series of creative techniques aimed at an organized systematic effort directed at analyzing the function(s) of products, services, equipments, processes or procedures for the purpose of accomplishing all the required functions at the lowest total cost, which expression covers not only initial cost, but also ownership cost covering operating/maintenance/disposal costs, etc, throughout the desired or specified life cycle of the article or subject under study. For details *see* IS 11810.

7.15.1.2 Value engineering results in the increased use of alternative less expensive material, cheaper design, weight reduction, new methods of manufacturing, indigenisation etc, to give the same or better performance, quality and efficiency at a lower overall cost.

7.15.2 *Usage in Terotechnology*

In terotechnology this technique should first be applied to the design of the product or service envisaged for the project and then to the assets with which these are to be produced.

7.16 Technique 16 — Reliability and Maintainability Analysis [*see* Table 2, Phase (iii)(1) and (iv)(2)(a)]

7.16.1 *Basic Principles of Technique*

7.16.1.1 Reliability and maintainability are important performance functions for any new or proposed asset. In combination with the associated maintenance support facilities provided for an asset, these functions will be the principal contributors towards the availability of the asset and thus its potential for output and ultimately profit.

7.16.1.2 Future reliability values are generally expressed in terms of probabilities of success or failure and the distribution functions of such probabilities.

7.16.2 *Usage in Terotechnology*

At the design stage for any new asset, the asset design should be studied from both a reliability and maintainability point of view as essential steps in the assessment of the likely availability of the asset in service. Such studies and their subsequent analysis should be carried out in such a way that the prospects for optimizing and refining the designs to give improved availability performances and minimizing both downtime and maintenance costs can be carried out. These studies are therefore key elements in the assessments of life time costs and ultimately in the viability of the project and its profitability.

7.16.3 *Related Techniques*

Plant History Files : Technique 17.

Performance Analysis : Technique 19.

7.17 Technique 17 — Plant History Files (Asset History Files) (Lifetime Records) [*see* Table 2, Phase (iii)(1), (iv)(1)(a), (iv)(1)(d) and (v)]

7.17.1 *Basic Principles of Technique*

7.17.1.1 Although particularly relevant to plant and equipment, history files are also relevant to, and should be kept for, other assets such as buildings and structures.

7.17.1.2 The elements to be recorded in history files should include the following:

a) Operations with particular reference to operation in abnormal conditions;
b) Failures and details of rectification;
c) Other maintenance including preventive maintenance;
d) Inspections/examinations and records of findings;
e) Tests carried out and results;
f) Modifications carried out; and
g) Modifications proposed but not carried out.

7.17.2 *Usage in Terotechnology*

7.17.2.1 The principal usage of history files is to provide data on which analyses are carried out. Collection of these data is primarily carried out during commissioning and subsequent usage of the asset but certain data should also be collected during manufacture and erection which could relate to the health of the asset and its subsequent performance.

7.17.2.2 Analysis of the history can be used to identify weaknesses in the design of the asset and then used to propose modifications to the asset and/or strategies to minimize the consequences of such weaknesses.

7.17.2.3 Different analysis can be carried out to obtain data on reliability of the asset (*see* Reliability/ Maintainability Analysis : Technique 16) or a need for preventive maintenance.

NOTE — Consideration should be given to the use of information technology in such techniques.

7.18 Technique 18 — Supplier Assessment [*see* Table 2, Phase (iii)(1)]

7.18.1 *Basic Principles of Technique*

7.18.1.1 Vendor assessment is carried out on any main or sub-contractor potentially involved with a tender for the supply of the asset. The assessment is concerned with the ability of the main or sub-contractor to meet all the requirements of the user organization in respect of the components being offered. This includes the long term support of the components or asset concerned. For details refer IS/ISO 9001 and IS 12040.

7.18.1.2 Matters normally included in the assessment are the following:

a) Long-term financial stability of the contractor;
b) Proven ability to produce and deliver reliably to cost, specification and to the date and quality required; and
c) Ability and willingness to give appropriate technical support to their product for the duration needed by the user organization.

7.18.2 *Usage in Terotechnology*

This technique mainly applies to the acquisition phase but may also to potential suppliers other than the original manufacturers offering to undertake modification or maintenance of the asset or, in some cases, to provide an alternative supply of material for the asset.

7.19 Technique 19 — Performance Analysis [*see* Table 2, Phase (iii)(1)]

7.19.1 *Basic Principles of Technique*

7.19.1.1 This technique employs data from existing assets and is used to predict the likely performance of a new asset. If comparison between two or more tenders for the new asset is being carried out the exercise may be limited to those features which are likely to affect costs and output.

7.19.1.2 The data and analysis should be concerned with all features of performance that influence output and costs.

7.19.2 *Usage in Terotechnology*

7.19.2.1 This technique is essentially used in the acquisition phase but relies entirely on data collected from existing and past assets and analysis of this data.

7.19.2.2 During the lifetime of an asset, the collection of appropriate data is most important although it may only be used in the assessment of assets offered for future projects.

7.19.3 *Related Techniques*

Plant History Files : Technique 17.

7.20 Technique 20 — Ergonomics [*see* Table 2, Phase (iii)(1)]

7.20.1 *Basic Principles of Technique*

Ergonomics is the study of the inter-relationship between machines or equipment and personnel who are required to operate or carry out other tasks on them. In particular the study compares the needs of the machine with the reach and strength capabilities of a likely human operator. These particularly apply to the layout and types of control and display incorporated in the design of the asset. Similar considerations need to be applied to the needs and capabilities of personnel carrying out servicing or maintenance of the asset.

7.20.2 *Usage in Terotechnology*

This technique is predominantly used in the design period of the acquisition phase.

7.21 Technique 21 — Environmental Planning [*see* Table 2, Phase (iii)(1)]

7.21.1 *Basic Principles of Technique*

Environmental planning concerns the effects of the inter-relationships of the proposed asset and the environment into which it is proposed to introduce it. For details refer IS/ISO 14001.

7.21.2 *Usage in Terotechnology*

In terotechnology, the impact of the proposed asset on the environment into which it is proposed to introduce it needs to be considered at all stages. In the concept/ investment decision phase, the likely impact and the acceptability of this, or the cost of making it acceptable needs to be considered in the initial viability studies. In many cases formal approval of its acceptability, by planning consent, which is regulated by specific statues and by laws, may be necessary before proceeding to the acquisition phase. During the acquisition phase, observance of statutory constraints is seldom sufficient. The asset itself, or its mode of delivery, erection and commissioning may impact upon 'environment' and such impacts should be eliminated, if possible, or minimized as far as is reasonably practicable. During the Operation and Maintenance phase and in the Disposal phase, further, different impacts may arise and should be treated similarly to minimize problems and potential costs.

7.22 Technique 22 — Flow Charts [*see* Table 2, Phase (iii)(1) and (v)]

7.22.1 *Basic Principles of Technique*

Flow charts are a method of illustrating process flows of all types. The applications can range from a manufacturing process carried out in steps, to a chemical process or even to the handling of paperwork in an office.

7.22.2 *Usage in Terotechnology*

7.22.2.1 In terotechnology, flow charts are used to illustrate process flows undertaken within the bounds of the asset. Whilst flow charting is of use to all parts of the user organization it is a technique of particular value to those who are to operate the asset. As such, flow charts are principally incorporated in the technical manual but earlier submissions, in this form may be appropriate for use in specifications, design assessments, and Acquisition phase documentation.

7.22.2.2 Flow charts are also used in conjunction with critical path analysis (*see* Technique 24).

7.22.2.3 Decision trees are a specialized type of flow diagram. A decision tree shows the flow of possible courses of action, usually in the face of chance events, in the form of a branching network. The decision tree technique can be used in maintenance problems where a considerable number of uncertain or probabilistic factors make it difficult to estimate the combined effect of these facts in an intuitive way.

7.23 Technique 23 — Control of Waste [*see* Table 2, Phase (iii)(1)]

7.23.1 *Basic Principles of Technique*

Waste can arise in most phases of a project and will take many forms. Each type of waste has to be considered for potential hazards to the general public either from its nature or from its extent. Certain waste materials will be covered by specific statutory regulations regarding disposal locations and/or their handling; this may include containment. Even where no specific statutory restraints exist, care needs to be exercised lest waste causes other problems, such as contamination of waterways, or causes a nuisance to the general public or individuals.

7.23.2 *Usage in Terotechnology*

7.23.2.1 In the acquisition phase, particularly during erection of the asset, waste can arise from civil works and the removal of protection and preservation of components before they are put to work. Most waste however is likely to arise during the working lifetime of the asset either from the processing of feedstock into the product or from operation of the asset and maintenance carried out on it.

7.23.2.2 Correct treatment of waste can cause significant costs which should be foreseen and taken into account in the concept/investment decision phase. In correct handling of waste is likely to result in significantly higher costs.

7.23.3 *Related Techniques*

Environmental Planning : Technique 21.

7.24 Technique 24 — Construction Analysis [*see* Table 2, Phase (iii)(2) and (v)]

7.24.1 *Basic Principles of Technique*

In major project, the optimum feasible sequence of individual tasks in the construction, erection and installation of the asset has to be determined in advance. This is necessary to avoid any abortive work and to minimize time and costs. In most cases there will be distinct limitations on the ability to store components on site before they are incorporated into the asset. Thus the timing of deliveries of components and materials to the site has to be closely coordinated with the final construction plan. For details *see* IS 14580 (Part 1).

7.24.2 *Usage in Terotechnology*

In terotechnology, the analyses of the tasks involved in the construction/erection/installation leading to the final optimized construction plan need to be monitored as the design of the asset progresses. This will take place early in the Acquisition phase.

7.24.3 *References*

7.25 Technique 25 — Modelling [*see* Table 2, Phase (iii)(2)]

7.25.1 *Basic Principles of Technique*

The term tends to be used in two distinct ways. In the first, small scale physical models of the proposed asset are constructed as aids to studies of the layout of the asset.

The term is also used in relation to the mathematical modelling of a physical process, usually as a step towards the use of computers in representing the process performance.

7.25.2 *Usage in Terotechnology*

7.25.2.1 In terotechnology, physical scale models are used in Acquisition phase generally at the design stage. These models are particularly useful in checking the asset design to ensure that there are no physical interferences of parts either in the completed asset or during construction and/or erection. The models are also useful in checking operational and maintenance aspects from the point of view of feasibility. More detailed studies of operability and maintenance accessibility can be gained from life size mock-ups of parts of the asset whenever difficulties are anticipated.

7.25.2.2 The mathematical modelling techniques tend to be used as part of computer studies and thus may be applied in any phase of the project.

7.26 Technique 26 — Design Schedules [*see* Table 2, Phase (iii)(3)]

7.26.1 *Basic Principles of Technique*

7.26.1.1 Schedules detailing all the individual elements of the design of the proposed asset are drawn up as part of the management of the design process.

7.26.1.2 Sub-schedules are usually drawn up for most major projects and list those design elements which have be submitted to the user, his agents or to some statutory body for approval and for the management of this process.

7.26.2 *Usage in Terotechnology*

These schedules are principally used in the Acquisition phase. In certain cases where designs have been officially approved, the schedules are retained into the Useful Life phase and may be used to index associated drawings, certificates, etc.

7.27 Technique 27 — Quality Management System [*see* Table 2, Phase (iii)(3) and (iii)(5)]

7.27.1 *Basic Principles of Technique*

Quality management is top management oriented system which sets out various processes to be implemented by the organization, which would ensure that the organization is capable of producing quality goods consistently. Various processes include those for top management, resource management, product realization and continual improvements. For details *see* IS/ISO 9000, IS/ISO 9001 and IS/ISO 9004.

7.27.2 *Usage in Terotechnology*

In terotechnology two different areas of activity will be influenced by the application of quality programmes. In the first instance there will be the application of the quality programme of the supplier in the production and supply of the asset. Subsequently the user will be involved in devising and operating the quality programme in respect of the product(s) from his asset.

7.28 Technique 28 — Quality Assurance Methods [*see* Table 2, Phase (iii)(3)and (iv)(1)(c)]

7.28.1 *Basic Principles of Technique*

Quality Assurance embraces all activities and functions concerned with the attainment of quality, rather than the narrower sense only of provision of proof associated with the word assurance: it includes the determination and assessment of quality. Quality is itself identified as the totality of functions and characteristics of a product that bear on its ability to satisfy a given need. Essentially this needs to apply to the complete needs of the user of the product.

7.28.2 *Usage in Terotechnology*

7.28.2.1 The initial concern to the user of an asset will be the application of quality assurance to all the activities involved in the provision of the asset. In this connection his asset is the product of his supplier and his concern will be for the application of quality assurance in the design, manufacture or erection and supply of his asset and its constituents. These are features of all the phases of the project up to the final commissioning of the asset.

7.28.2.2 During the operation and maintenance phase of the asset, the concern changes to the quality assurance that the user needs to apply to the product(s) from his asset in meeting the needs of his customers.

7.29 Technique 29 — Test Procedures [*see* Table 2, Phase (iii)(3)]

7.29.1 *Basic Principles of Technique*

7.29.1.1 These are procedures detailing tests carried out progressively on the asset to prove that it is fully satisfactory and complies with the specification and meets such guarantees as are offered by the supplier.

7.29.1.2 The test procedures, in toto, may be scheduled in a network form. Initially the tests are carried out on materials being used, then on components as they are manufactured and erected and finally on systems and the asset as a whole. The tests are aimed at proving correct functioning, safety and the correct performance of safety devices and finally on performance of the asset, including performance for which guarantees have been offered.

7.29.2 *Usage in Terotechnology*

These are principally applied in the final erection and commissioning stages of the Acquisition phase. The tests may be appropriate and applied following major work on the asset to prove it continues to be satisfactory.

7.30 Technique 30 — Financial Analysis and Budgets [*see* Table 2, Phase (iii)(3)]

7.30.1 *Basic Principles of Technique*

The proper management of a project requires the prior establishment of targets to be met during the life cycle of the proposed new asset. Targets in respect of costs and income within a given time period are established in the form of budgets. Analysis of the budget will permit predictions as to the finance required to initiate and serve the project as a whole.

7.30.2 *Usage in Terotechnology*

In terotechnology, the first budget for any new project needs to be established and approved at the very start of the acquisition phase. Thereafter, budgets will be set and revised throughout the full life cycle of the asset.

7.31 Technique 31 — Network Analysis [*see* Table 2, Phase (iii)(4) and (iii)(5)]

7.31.1 *Basic Principles of Technique*

7.31.1.1 Network analysis is based upon presentation of the individual tasks that have to be performed to complete a given project. In particular the presentation identifies the inter-relationships between individual tasks which can only be performed in a given sequence. A diagrammatic presentation of all such relationships appears in the form of a network.

7.31.1.2 Analysis of the network will identify those tasks which fall on the critical path of the project and will identify the extent of slack that can be allowed on tasks which do not fall on the critical path. More detailed analysis of the network can show the effect on project duration of varying the resources deployed to individual tasks, the effects of limited resources and the loading of specific resources throughout the project. For details refer IS 7337 and IS 14580 (Part 1).

7.31.1.3 The most important techniques of network analysis are Critical Path Method (CPM) and Programme Evaluation Review Technique (PERT).

7.31.2 *Usage in Terotechnology*

7.31.2.1 This technique is particularly used in the acquisition phase when the project under consideration is for the manufacture, erection and commissioning of the asset. Optimization of this phase is carried out applying this technique to the whole phase and also to segments of the phase.

7.31.2.2 The technique can be similarly used during the operation and maintenance phase to plan and optimize certain production activities and maintenance activities, especially major overhauls, modifications or repairs.

7.32 Technique 32 — Bar Charts [*see* Table 2, Phase (iii)(4)]

7.32.1 *Basic Principles of Technique*

Bar charts are a simplified form of presentation for the various tasks which are involved in a total project. They illustrate against a time ordinate the various tasks to be carried out, times of starting and durations allowed and who, or what resources, are allocated to the task. Inter-relationships between the tasks may not be shown, thus differing from the network analysis presentation. For details *see* IS 7200(Part 1) and IS 7200(Part 2).

7.32.2 *Usage in Terotechnology*

This technique is used for the same series of tasks as network analysis but mainly in support of management control of the resources rather than for analysis and optmization. The layout may be arranged to group certain features together such as all tasks involving a particular resource.

7.32.3 *Related Techniques*

Network Analysis : Technique 31.

7.33 Technique 33 — Progress Assessment [*see* Table 2, Phase (iii)(4)]

7.33.1 *Basic Principles of Technique*

This technique includes the following:

a) Monitoring the rate of achievement of targets (financial, material, environmental improvements, etc); or
b) Assessing the position in a critical path method of specific project(s); or
c) Checking the results of employee training.

7.33.2 *Usage in Terotechnology*

7.33.2.1 Progress assessment is used in all phases of a project from concept/investment decision, through acquisition and useful life to disposal. It is, however, mostly used during the procurement stage, or to monitor the rate of achieving the following:

a) Changes in working patterns;
b) Targets for market levels of shares; and
c) Necessary reactions to external forces.

7.33.2.2 Targets will have been set either during the concept/investment decision phase, or by external agencies (that is a change in legislation). The assessment is essential for monitoring management of time and gauging if the resource input is too low, too high or on target. The technique is also used to predict changes required to targets if resources available cannot change. The progress assessment technique forms an essential element in the preparation of annual and quarterly reports. For details *see* IS 7337.

7.33.2.3 *Related Techniques*

Network Analysis : Technique 31.

Quality Assurance Programme : Technique 27.

Bar Charts : Technique 32.

7.34 Technique 34 — Hazard Analysis [*see* Table 2, Phase (iii)(4) and (v)]

7.34.1 *Basic Principles of Technique*

The technique involves a critical analysis of the asset and how it is to be operated and maintained, to ensure that all hazards to personnel or to the general public are eliminated as far as is practicable. For details *see* IS 15001.

7.34.2 *Usage in Terotechnology*

This technique is applicable throughout the life of the asset, although it is particularly relevant during the acquisition phase. At this stage, action to modify the asset to avoid a hazard can usually be taken at least cost.

7.34.3 *Details of Technique and Applications*

7.34.3.1 Most latent hazards, due to failure in the asset, should be taken care of by designers of the asset or its components. Certain hazards are covered by statutory requirements. In this context the user may need to consult specialists who may be outside his organization. Surveys of the plant to identify hazards should be carried out, ideally by experienced staff appointed to operate or maintain the asset. These surveys should check that there are appropriate means of escape in the event of fire, etc. Fire risks and fire protective devices should be reviewed using the specialist knowledge of the local authorities.

7.34.3.2 Compliance of the asset with local or other statutory authority requirements should be a specifically identified feature of the overall plan and covered by appropriate contractual arrangements.

7.34.3.3 *Related Techniques*

Technical Manuals : Technique 35

Project Design Appraisal : Technique 10.

7.35 Technique 35 — Technical Manuals [*see* Table 2, Phase (iii)(4), (iii)(5), (iv)(1)(a), (iv)(2)(a) and (v)]

7.35.1 *Basic Principles of Technique*

7.35.1.1 Technical manuals are the principal means whereby the supplier or manufacturer of an asset communicates to the user(s) all the information needed for them to operate and maintain the asset efficiently and safely.

7.35.1.2 The scope and arrangement of the manuals should be contractually required by the user in an appropriate specification. The scope will normally include a full technical description of the asset, instructions on commissioning, operating and maintaining it together with suggested forms of maintenance policy that would be appropriate. In most cases instructions on erection and/or installation and disposal should be included. Spares lists and suitable means of identifying and describing components should also be give.

7.35.2 *Usage in Terotechnology*

The technical manuals, which should be issued to a user prior to commissioning the asset, are to provide him with all necessary information on which to base his own commissioning, operation, and maintenance strategies and to enable him to issue his own detailed instructions for these activities. Analysis of these should also enable him to establish suitable manning and support arrangements.

7.36 Technique 36 — Expected Cost to Completion [*see* Table 2, Phase (iii)(4)]

7.36.1 *Basic Principles of Technique*

When the acquisition of an asset involves extended supply, erection and commissioning activities and where payments for this are dictated by contracts with variation clauses, determination of the extent and timing of future payments to complete the acquisition has to be carried out from time-to-time. The sum of such future payments is termed the 'expected cost to completion'. This sum may include nominal amounts as contingencies for future problems in known risk areas.

7.36.2 *Usage in Terotechnology*

This technique is used as part of the progress monitoring carried out during the Acquisition phase. The estimated cost to completion plus the value of payments already made has to be compared with the agreed budget and the authorization given for the project by the user organization.

7.36.3 *Related Technique*

Network Analysis : Technique 21.

7.37 Technique 37 — Handling and Storage [*see* Table 2, Phase (iii)(4)]

7.37.1 *Basic Principles of Technique*

7.37.1.1 During the erection of an asset individual components have inevitably to be handled. This can impose stresses upon the component which are different from and could be greater than those to which it would be subjected during normal use. Appropriately selected methods of handling and the selection of specified lifting points can minimize the risk of failures arising through handling activities. Movement of sequences, etc, should be selected to avoid these dangers.

7.37.1.2 Should a component be delivered to site ahead of its incorporation into the asset, it will inevitably need to be stored for a period of time. The nature and location of storage should be chosen to avoid damage from other activities and the component should be preserved to avoid environmentally induced deterioration. In practice, the greatest risk often arises from removal of transit protections to examine and check the item on arrival and failure to restore protection during the storage period.

7.37.1.3 Precise techniques and procedures should be considered at the design stage and should be specified both in the contract documentation and in the technical manual under the heading 'Handling and storage of components'.

7.37.2 *Usage in Terotechnology*

Principally the techniques are applicable during acquisition but similar problems can arise and similar techniques can apply during maintenance activities.

7.38 Technique 38 — Structural Safety Limits [*see* Table 2, Phase (iii)(4)]

7.38.1 *Basic Principles of Technique*

The strength of each element of the structure of the asset will have been determined as part of the design of the asset. The particularly relevant aspect is the load bearing capacity of structural elements such as beams and floors.

7.38.2 *Usage in Terotechnology*

7.38.2.1 In terotechnology, the load bearing capacity of elements has to be considered firstly to meet the loads applied by the components of the asset themselves and those resulting when components and elements of the asset are moved during either erection, maintenance or dismantling. Such loads will include those arising from the introduction of equipment to be used in maintaining or servicing the asset.

7.38.2.2 These considerations initially arise during the design period of the acquisition phase but should be reconsidered in the light of any changes in operation or maintenance techniques or facilities from those originally considered. A complete schedule of structural safety limits should be provided for this purpose in the technical manual.

7.39 Technique 39 — Commissioning Procedures [*see* Table 2, Phase (iii)(5)]

7.39.1 *Basic Principles of Technique*

7.39.1.1 The purpose of the commissioning stage for a new asset is to confirm that it has been constructed and/or erected correctly, and that it will perform correctly and safely in the manner laid down in the specification and in any guarantees that have been offered. During this time, all controls, etc, that need to be preset are adjusted to their optimum settings and then locked.

7.39.1.2 Where safety protective devices are concerned these have to be proven over the full range of possible situations for which they are devised. At the same time it is essential that the procedures for testing these devices do not themselves involve risks to personnel or to the asset. For example, an overspeed device on a prime-mover is normally provided to protect it against loss of its load. In testing the device, it should first be tested by a restricted load rejection and subsequently at a number of steps involving progressively increasing levels of load throw-off before finally being tested with a rejection of its rated load.

7.39.1.3 To ensure that the commissioning procedures are comprehensive and safe, it is desirable that these be prescribed in full detail and in writing: ideally these should be considered and agreed between the supplier and the user. It is also recommended that provision for these should be included in the contract for supplying the asset.

7.39.1.4 The detailed procedures to be followed will depend entirely upon the asset concerned and can also be influenced by the terms of the particular contract between the supplier and the user.

7.39.2 *Usage in Terotechnology*

7.39.2.1 The principal usage of the commissioning procedures is during the commissioning stage for the new asset, that is, following manufacture and erection but before the Operation and Maintenance phase begins.

7.39.2.2 Similar but less extensive procedures are sometimes necessary following any major refurbishment or modification of the asset.

7.39.2.3 During normal operation, some of the procedures may be repeated routinely to confirm that the asset remains in a satisfactory condition. This particularly applies where safety devices are involved.

7.40 Technique 40 — Training Schedule [*see* Table 2, Phase (iii)(5)]

7.40.1 *Basic Principles of Technique*

7.40.1.1 A training schedule details the special training required by each grade or member of staff employed to operate, maintain or support the asset before they can carry out their specified duties in respect of the asset. The training covered by the schedule is that required in addition to all educational, professional or technician/ skill training to the required qualification level.

7.40.1.2 The training may involve any or all of the following:

a) Theoretical training by lectures, study etc;
b) Study of technical manuals supplied with the asset;
c) Acquaint training in or on the asset;
d) Simulator training or training on mock-ups of the asset;
e) Dry-runs or live operations of the asset under supervision.

7.40.2 *Usage in Terotechnology*

7.40.2.1 This technique is put into effect before the asset is commissioned or, in the case of staff recruited or promoted to fill a vacancy, before that person is allowed to carry out his or her appointed duties in respect of the asset.

7.40.3 *Related Techniques*

Employee Training : Technique 55.

7.41 Technique 41 — Performance Guarantees [*see* Table 2, Phase (iii)(5)]

7.41.1 *Basic Principles of Technique*

These guarantees are agreed under the terms of the contract for the asset and may set terms for payment or rebate according to the degree to which a specified performance characteristic exceeds or falls short of a guaranteed figure.

7.41.2 *Usage in Terotechnology*

7.41.2.1 This technique is mainly applied during the acquisition phase. It commences with agreed terms being set in the contract between the supplier and the purchaser. Normally tests on the completed asset are conducted during commissioning; the results of these tests are used to determine the actual performance relative to the guaranteed figure.

7.41.2.2 Guarantees are usually sought on those performance aspects which determine specific operational costs of the asset, for example output, efficiency, reliability. Details are determined by the asset involved and the qualities being guaranteed.

7.41.3 *Related Techniques*

Test Procedures : Technique 29.

7.42 Technique 42 — Order Processing [*see* Table 2, Phase (iv)(1)(a)]

7.42.1 *Basic Principles of Technique*

As orders for the product are received, a production plan needs to be devised which takes into account the known and predicted demands for the product. The production plan clearly should be within the capacity of the asset after due allowance is made for planned and unplanned downtimes. Optimization of the production plan should follow, taking into account the effects of loadings on the asset, personnel requirements and likely maintenance consequences.

7.42.2 *Usage in Terotechnology*

This activity takes place in the useful life phase.

7.42.3 *Related Techniques*

Queueing Theory : Technique 14.

7.43 Technique 43 — Statutory Inspections [*see* Table 2, Phase (iv)(1)(a) and (iv)(2)(a)]

7.43.1 *Basic Principles of Technique*

The requirement to inspect and possibly test certain components of the asset, at intervals set by time or operational usage, are prescribed in various statutory regulations and some laws.

7.43.2 *Usage in Terotechnology*

7.43.2.1 Allowance for these statutory inspections has to be made in both production and maintenance plans and programmes. As such these will be activities in the useful life phase of the asset.

7.43.2.2 The requirement should first be considered in the concept/investment decision and Acquisition Phases and due allowances made for these requirements, and their effects on output, in specifications, designs and assessments. There will be cost implications.

7.44 Technique 44 Operator Maintenance [*see* Table 2, Phase (iv)(1)(a)]

7.44.1 *Basic Principles of Technique*

7.44.1.1 Certain tasks which come within the definition of maintenance do not require a level of skill appropriate to a qualified maintenance personnel. This particularly applies to those activities which come within the definition of 'servicing'.

7.44.1.2 Such activities are often within the capabilities of those employed to operate the asset, given appropriate directions and training. Further more, it frequently happens that the timing of such activities causes them to fall at times when it is inappropriate or inconvenient to deploy skilled staff to perform them whereas they can be undertaken by operational staff as part of their normal duties.

7.44.1.3 Tasks which fall naturally into this category are cleaning of plant, lubrication and replenishment of other consumables such as coolants. In special circumstances it may be appropriate to use a skilled craftsman as an operator in which case the scope of tasks to be handled under this technique can be greatly extended. Such a situation is particularly appropriate to major transport assets such as ships.

7.44.1.4 The allocation of maintenance tasks to this technique should be a management function and decisions should be based on achieving an overall optimum economic return.

7.44.2 *Usage in Terotechnology*

The tasks and this strategy fall into the operation and maintenance phase of the asset.

7.45 Technique 45 — Life Assessment Residual Life Assessment [*see* Table 2, Phase (iv)(1)(a)]

7.45.1 *Basic Principles of Technique*

7.45.1.1 One of the most common causes of an asset's failure to perform is the degeneration of one or more of its components. Where this only involves minor components these can be replacement can be both costly and prolonged. In the extreme, complete replacement of the asset may have to be contemplated. If failure were to occur, hazards to personnel or other components and/or assets might result and in such cases failure should be avoided by preventive action. Even when no hazards are presented, preventive action can usually mitigate the economic consequences of failure of a major component due to degeneration to a point where it can no longer function, that is the point of life exhaustion and the end of its physical life.

NOTE — The physical life of an asset may be described as the tine between its creation and ultimate failure when repair and maintenance is no longer viable. However, an asset can decrease in value before the end of its physical life for various reasons.

7.45.1.2 The technique is devised to predict when this point is likely to be reached; in so doing estimates are always aimed at erring on the side of safety, that is to say on the early side, thereby avoiding failure in service. However, for economic reasons it is also desirable, as the life exhaustion point is approached, to apply more accurate (and usually more sophisticated) methods in carrying out the assessment.

7.45.1.3 The methods used in applying the technique will vary according to the component and degenerating processes involved. Essentially each methods will comprise a number of steps when applied to a given component, as follows:

a) Identify the component and the degenerating processes it is subjected to (this may be creep, fatigue, corrosion, erosion, wear, etc, or a combination of these).
b) Estimate the rate of progress of such degeneration on the component.
c) Identify the extent of degeneration that has already taken place.
d) Identify the further extent of degeneration that the component can tolerate before failing.
e) From the above data, estimate the time needed for degeneration to reach the life exhaustion point.

7.45.2 *Usage in Terotechnology*

The technique is initially used by the asset's designer in matching the design to the specified life for which the asset is intended. During the evaluation and planning stages, the user should make his own assessments as a step in his assessment of the need for, and long-term costs of, support for the asset and implications regarding its usage. During commissioning and subsequent use of the asset such predictions should be periodically reviewed in the light of developing experience and direct observation, measurements or tests on the component.

7.45.3 *Example*

7.45.3.1 In a large high pressure steam boiler, the final superheater outlet header is most likely to fail through creep. Life assessments of the component are normally carried out in four stages.

7.45.3.2 Stage 1 is applied initially by the designer: in this he predicts the life of the header using a calculated hoop stress, based on the design pressure of the header, and lower published bound data on creep life/stress for the material type concerned at the design temperature for the header material.

7.45.3.3 Stage 2 is applied during the early operation of the boiler. The design pressure (which is above the normal operating pressure of the boiler) is still used in the estimation and, after the header material has been confirmed, lower bound data for creep life/stress is again used, but now metal temperatures deduced from recorded histories of steam temperatures measured in operation are used. These deduced temperatures are designed to be on the safe side.

7.45.3.4 Stage 3 takes over when a significant fraction of the predicted life has been used. At this stage, thermocouples are directly attached to the header and these directly measured metal temperatures are now used in the predictive exercise.

7.45.3.5 Finally in Stage 4, adopted when the previously estimated life exhaustion point is approached, direct measurements of creep distortion are taken and detailed metallographic examinations are carried out on samples of the header material to determine the true extent of creep damage and thence to determine the true life expectation remaining.

7.46 Technique 46 — Operator Instructions [*see* Table 2, Phase (iv)(1)(a)]

7.46.1 *Basic Principles of Technique*

7.46.1.1 The essential operation instructions for any new asset should be provided as part of the associated technical manual.

7.46.1.2 When the asset involved is a domestic appliance, or of similar complexity and is intended to be operated by a single person, such instructions as are given in the manual may be sufficient. However, when the user is an organization and several different persons may need to operate the asset, albeit singly, this may not be sufficient. This will be the case in those particular circumstances where the operation procedures are unusual or complex or where safety is involved. In such cases the user needs to consider how best to promulgate the operation and safety guidance necessary. This may be by instructions directly affixed to the asset in an appropriate manner, by training, by pocket sized instruction cards or by a combination of these methods.

7.46.1.3 When the asset is a complex machine or system to be operated by a team of personnel, the user needs to establish a proper organization for the team and a hierarchical structure of authority within it for the execution of all necessary operations including emergency procedures. The promulgation of detailed operating instructions, for use within the team's organizational structure, becomes even more important in these circumstances. Similar methods of achieving this to those described above remain appropriate. For extremely complex systems, a hierarchical approach to the instructional documentation may be appropriate.

7.46.2 *Usage in Terotechnology*

7.46.2.1 Operator instructions are essentially needed for the operation and maintenance phase of the asset. However such instructions will also be needed during the commissioning stage whilst the asset is being 'commissioned'.

7.46.2.2 Where safety is involved, and particularly where statutory obligations have to be met, operating instructions should be provided before the asset is commissioned. In all cases they need approval by the user and may also need to be considered and approved by a statutory inspectorate.

7.46.3 *Related Techniques*

Technical Manuals : Technique 35.

7.47 Technique 47 Material Needs [*see* Table 2, Phase (iv)(1)(b)]

7.47.1 *Basic Principles of Technique*

7.47.1.1 The material needs of a project, after deliver of the asset, essentially fall into two categories. These are as follows:

a) Those materials used as feed into the production process, which are therefore incorporated into the product; and

b) That material needed to operate and maintain the asset itself.

7.47.1.2 The latter category will include spares for the asset and its components.

7.47.1.3 It is essential that the user forecasts the likely requirements for both sets of materials and ensures their availability for the lifetime of the asset. In some instances the user may have to take action himself to ensure the continuing availability of a material by advance ordering and stocking. This is most likely to apply to spares as a result of specific components of the asset becoming obsolete as far as their sources of supply are concerned.

7.47.2 *Usage in Terotechnology*

These activities relate to the working life of the asset, the operation and maintenance phase.

7.48 Technique 48 — Work Study [*see* Table 2, Phase (iv)(1)(b) and (iv)(2)(a)]

7.48.1 *Basic Principles of Technique*

The primary purpose is to derive methods and times for activities and from these to determine manning levels and patterns of working. Essentially the technique comprises two aspects, method study and work measurement. In the former, alternative methods of carrying out the activity are considered and assessed to determine an optimum. This may be in terms of better utilization of materials, equipment or manpower or may be in terms of cost or performance according to the circumstances. Work measurement is designed to establish the work content and time required for specific tasks when carried out by a specified person. This may involve direct measurement of the task (time study) or synthesis from knowledge of the elements of the task for which time studies have been carried out in the examination of other tasks (synthesis) or comparisons with other, generally similar tasks (comparative estimating). For details refer IS 6363, IS 13407 (Part 1) and IS 13407 (Part 2).

7.48.2 *Usage in Terotechnology*

7.48.2.1 This technique is essentially applied to activities carried out during the productive life of the asset such as its operation and maintenance. During the evaluation and planning phases of a project the technique is used to predict the manning requirements and from these the recruitment and training needs as well.

7.48.2.2 The technique can also be applied in a similar fashion and to the same ends during considerations of the commissioning stage and disposal phase.

7.49 Technique 49 — Stock Control [*see* Table 2, Phase (iv)(1)(b) and (iv)(2)(a)]

7.49.1 *Basic Principles of Technique*

7.49.1.1 This technique is aimed at determining the most efficient and economic ways in which a stock of materials should be set up and managed. The optimization process needs to take into account the demand pattern, and the additional costs of, on the one hand, early ordering and on the other hand, not having sufficient stock when required. Other factors include the costs of storage and variations in the cost of new stock with the size of any replenishment order and the lead times within which replenishment orders can be fulfilled.

7.49.1.2 The risks involved in each step of the process should be evaluated and considered.

7.49.2 *Usage in Terotechnology*

This technique is principally applied in respect of materials used in the process carried out by the asset: it can also be applied similarly to stocks needed for the maintenance of the asset. As such, these techniques are mostly used during the useful productive life of the asset. However, in the evaluation and planning phases, estimates have to be made to ensure the provision of adequate support resources, such as stores buildings, for the prime asset being considered.

7.50 Technique 50 — Data Logging [*see* Table 2, Phase (iv)(1)(b) and (iv)(1)(d)]

7.50.1 *Basic Principles of Technique*

7.50.1.1 Proper management of the operation of most assets will require the measurement and recording of certain data routinely. These data are used to monitor performance and in particular to identify abnormal performance that should be corrected by maintenance. This is the immediate use. Other data may be needed as a means of predicting the safe life remaining in the asset or a component of the asset.

7.50.1.2 Finally data should be recorded for use in feedback to improve the design of future assets.

7.50.2 *Usage in Terotechnology*

This technique is one that is applied in the operation and maintenance phase but should be started in the commissioning stage. If the data to be handled and recorded are extensive, consideration should be given to the use of computers to effect both the measurement, recording and analysis functions.

7.50.3 *Related Techniques*

Life Assessment: Technique 45.

7.51 Technique 51 — Control Limits [*see* Table 2, Phase (iv)(1)(b)]

7.51.1 *Basic Principles of Technique*

When a product from an asset has to meet a quality specification, limits have to be set for any variation from the desired values of designed characteristics. Operators need to adjust their actions to keep the product within these limits. For details refer IS 397 (all Parts).

7.51.2 *Usage in Terotechnology*

In terotechnology these limits are imposed in the Operation and Maintenance phase. To assist in keeping the product within these limits various techniques applied to the results of monitoring measurements on the product can predict trends. These will allow corrective action to be taken before an undue level of unacceptable product is produced.

7.52 Technique 52 — Operational Research [*see* Table 2, Phase (iv)(1)(c)]

7.52.1 *Basic Principles of Technique*

This is a generalized term for techniques carried out to determine the best way in which a particular task can be performed. This can involve work study and/or the design of the asset or the arrangements for its operation and maintenance to achieve the best results.

7.52.2 *Usage in Terotechnology*

In terotechnology, operation research is used in the acquisition phase to determine the most suitable design being offered for the asset and in the operation and maintenance phase, to optimize the operation and maintenance of the asset.

7.52.3 *Related Techniques*

Work Study: Technique 48.

Ergonomics: Technique 20.

Queueing Theory : Technique 14.

7.53 Technique 53 — Production Planning and Control [*see* Table 2, Phase (iv)(1)(c)]

7.53.1 *Basic Principles of Technique*

Good management of an asset requires that its operation is pre-planned within the capacity of the asset and with due regard to the needs of maintenance, to meet the demand for its product. Production control is exercised by management of the asset as far as possible to meet the production plans.

7.53.2 *Usage in Terotechnology*

Production planning and control is exercised in the operation and maintenance phase. The plan should conform as far as possible to the overall strategy and expectations developed in the concept/investment decision phase, modified as necessary by the actual demand for the product.

7.54 Technique 55 — Employee Training [*see* Table 2, Phase (iv)(1)(c)]

7.54.1 *Basic Principles of Technique*

Employee training is carried out to match staff to the needs of serving the asset.

7.54.2 *Usage in Terotechnology*

7.54.2.1 When a new asset is about to be commissioned and then operated it is unlikely that staff can be recruited who can immediately carry out its necessary operations, maintenance or support. Discrepancies between the standards of personnel recruited and those of personnel able to perform the above tasks reliably have to be eliminated by employee training. Whilst generally personnel will have been recruited with the required educational qualifications, it may be necessary to institute training to achieve the required professional or skill qualifications. In almost all cases there will be a further need for a greater or lesser extent of training to acquaint recruits with the new asset and work methods with respect to it.

7.54.2.2 Personnel new to the organization will also need a measure of induction training to ensure that they appreciate its purposes, policies and how their duties contribute to the corporate objectives as well as details regarding their duties, obligations and expectations. This training is important to personnel motivation and can influence performance.

7.54.2.3 After the asset is commissioned, recruitment reduces to the replacement of wastage but all new recruits will need similar training to the above. At the same time a measure of advancement training for existing staff to enable them to be promoted to more senior positions will be needed. According to circumstances this can be either in advance of a vacancy at a senior positions will be needed. According to circumstances this can be either in advance of a vacancy at a senior position or on notification that such a vacancy is arising or after a selection process. The principal factors to be considered in this process are:

a) Time needed to carry out such training;
b) Time that a vacancy at the senior position can be tolerated without affecting performance of the asset; and
c) Probability of such a vacancy arising.

7.55 Technique 56 — Energy Management [*see* Table 2, Phase (iv)(1)(c) and (iv)(2)(a)]

7.55.1 *Basic Principles of Technique*

The total energy inputs to the asset, energy transfers within the asset and energy losses from the asset should be studied. Action should be taken to ensure that all losses are minimized as far as it is economic to do so, for example by providing insulation to avoid heat losses. Energy recovery possibilities should also be considered.

7.55.2 *Usage in Terotechnology*

This aspect should first be considered in the design appraisal stage, followed up by measurements in the operation and maintenance phase. To carry out this latter requirement a measure of data logging will be necessary.

7.56 Technique 57 — Marketing Management [*see* Table 2, Phase (iv)(1)(c)]

7.56.1 *Basic Principles of Technique*

7.56.1.1 Before a new product is introduced to the market, action will have been taken by sales staff to advertise its features, availability and cost. In many cases, initial production will be based on the expected sales of the product.

7.56.1.2 Once a product is established, appropriate action needs to be taken by the sales staff to achieve sales which can be economically (and profitably) produced by the asset. The interaction between sales and project costs is such that close cooperation is needed to ensure that maximum profitability is achieved.

7.56.2 *Usage in Terotechnology*

The above activities are essentially carried out during the useful life phase of the asset.

7.57 Technique 58 — Reports [*see* Table 2, Phase (iv)(1)(d)]

7.57.1 *Basic Principles of Technique*

In terotechnology, effective communications between parties is the most important factor in achieving optimum life cycle costs and profitability. This particularly includes the feedback of data to assist in the design and assessments of successor projects. In this latter case, the study of the feedback data will normally take place a long time after the events to which the data relates. It is therefore most important that communications and records are complete, accurate, clear and as concise as is possible within these foregoing three objectives. Reports are the most common form of these communications relating to events, decisions and other matters of concern regarding the asset. The quality of reports in meeting the objectives noted above will materially affect the effectiveness of the communications concerned.

7.57.2 *Usage in Terotechnology*

7.57.2.1 Pressure of the moment may make it difficult for personnel to find time to prepare suitable reports on significant events, etc. Often this is merely used as an excuse for not writing a report, even when it is clearly a terotechnological necessity.

7.57.2.2 Because communications are such an important feature of terotechnology, management should insist on proper reports being prepared and circulated where needed to ensure proper terotechnological performances of other sections of the organization. Action to improve the quality of reporting should be taken where necessary.

7.57.2.3 The need for report arises in all phases of the project, but particularly during the useful life phase.

7.58 Technique 59 — Quality Records [*see* Table 2, Phase (iv)(2)(a)]

7.58.1 *Basic Principles of Technique*

The suppliers of an asset should be required to maintain records to substantiate conformance with all aspects of the specified requirements. This should include all aspects related to Quality Assurance, especially the details and results of all tests and inspections. These records should be made available to the purchaser/user if required, or to an agent acting on his behalf. For details refer IS/ISO 9000, IS/ISO 9001 and IS/ISO 9004.

7.58.2 *Usage in Terotechnology*

These records are particularly applicable to the production of the asset being required. Subsequently they may be similarly required for the output or products of the asset.

7.58.3 *Related Techniques*

Quality Assurance Methods : Technique 28.

Quality Programme : Technique 27.

7.59 Technique 60 — Plant Inventory [*see* Table 2, Phase (iv)(2)(a)]

7.59.1 *Basic Principles of Technique*

These inventories are detailed schedules listing every component and system comprising the asset.

7.59.2 *Usage in Terotechnology*

Plant inventory will normally be initiated as part of the contract documentation for use in monitoring the supply and erection and/or installation of the plant. At a later stage in the Acquisition phase, the inventory would be used to check the completeness of the supplied technical manual. During the operation and maintenance phase, the inventory should normally be held and maintained by the maintenance function and used as an index for total maintenance instructions and records.

7.59.3 *Related Techniques*

Plant History Files : Technique 17.
Life Assessment : Technique 45.
Resource Allocation and Planning : Technique 64.
Maintenance History/Analysis : Technique 69.
Repair/Replacement Optimization : Technique 70.

7.60 Technique 61 — Work Instructions [*see* Table 2, Phase (iv)(2)(a)]

7.60.1 *Basic Principles of Technique*

Instruction on how to carry out maintenance tasks should be included in the technical manual provided by the supplier to the user for the asset. However, in large organizations these alone are seldom adequate to control the work of the maintenance personnel properly.

7.60.2 *Usage in Terotechnology*

7.60.2.1 For each task allocated to a maintenance team, full instructions should be given which detail exactly how the task is to be carried out. These will include the maintenance instructions taken from the technical manual but will go into further details. All actions of a technical or administrative nature that are necessary for the safety of personnel and the asset need to be included together with such further details as are needed for ensuring the optimum performance of the task. This should include the tools needed course of the work should be specified.

7.60.2.2 These work instructions should initially be drafted during the commissioning stage and subsequently up-dated necessary during the useful life of the asset.

7.60.3 *Related Techniques*

Reports of Work Done : Technique 62.

7.61 Technique 62 — Reports of Work Done [*see* Table 2, Phase (iv)(2)(a)]

7.61.1 *Basic Principles of Technique*

7.61.1.1 A report of work done on an asset either as a result of maintenance or in the incorporation of a modification, should be made and recorded as soon as possible after completion of the work. The report should be in sufficient detail to meet any likely future need to refer to this data.

7.61.1.2 Reports of work done should also cover reports on inspections carried out. These reports may reveal shortcomings in functional efficiency before a failure occurs and so lead to remedial action which averts a failure and its possibly expensive consequences.

7.61.2 *Usage in Terotechnology*

In terotechnology these reports are a feature of the operation and maintenance phase. Reports should contain all data which might have implications for the strength, performance or life of the asset or its components and should include any critical parameters that could affect future maintenance operations, such as the fitting of spares, or be a datum for judgements on the development of wear or other degenerating mechanisms. Even the execution of routine servicing operations should be recorded, albeit in simplified form.

7.61.3 *Related Techniques*

Plant History Files : Technique 17.

7.62 Technique 63 — Maintenance Schedule [*see* Table 2, Phase (iv)(2)(a)]

7.62.1 *Basic Principles of Technique*

7.62.1.1 A maintenance schedule, describing what needs to be done, and when, in the maintenance of the asset, should be a requirement in the contents of the technical manual to be supplied with the asset.

7.62.1.2 On the basis of the advice given in the manual, the user, in the additional light of his own knowledge and experience, should establish, within his maintenance strategy, detailed schedules of planned preventive maintenance tasks. These should further establish what and how tasks should be performed as well as when and by whom.

7.62.2 *Usage in Terotechnology*

7.62.2.1 The maintenance schedules supplied as part of the technical manual will be used in the acquisition phase as a basis for helping to determine maintenance strategy and in the initial planning of preventative maintenance activities. They may also be used as an index in the determination of training and/or recruitment requirements for maintenance personnel. During the useful life phase of an asset, the schedules produced by the user form the final basis of the preventative maintenance plans.

7.62.2.2 The maintenance schedules should also include the activities of maintenance personnel and contractors in relation to statutory inspections, for example periodic inspection of boilers, pressure vessels and lifting tackle.

7.63 Technique 64 — Resource Allocation and Planning [*see* Table 2, Phase (iv)(2)(a)]

7.63.1 *Basic Principles of Technique*

Where a given work load comprises a large number of tasks, some of which can be planned and others which cannot, the resources to carry out the work need to be organized, as far as possible, to achieve maximum effect at minimum cost.

7.63.2 *Usage in Terotechnology*

7.63.2.1 In terotechnology the above term principally applies to the operation and maintenance phase. Resources of personnel and tools should be organized to meet the objective above. The optimum arrangement needs to be assessed in terms of the project for which the asset was acquired and not in relation to the maintenance function alone. If non-availability of the asset results in high costs or significant loss of revenue input, the allocation of resources should be such as to minimize downtime of the asset. At the same time, if asset breakdown is likely, allocation of some resources to non-urgent or non-essential tasks, such that they can be withdrawn immediately to tackle a breakdown, may be justified.

7.63.2.2 An important concept in the allocation of maintenance resources is reaction time. This is the period between a fault or failure being identified and its repair. The importance of this period can be assessed by the economic result of the fault or failure, some having severe cost consequences very quickly. The time taken to effect a repair also has a cost consequence and very short reaction times often have a cost premium. There is a need, therefore, to have a balance between the cost consequence of the failure and the cost of the reaction time.

7.63.2.3 As far as the production function is concerned, similar techniques should be applied in respect of feed materials and similar production resources. In some cases this may also apply to manpower. The basis of planning should be to achieve an output of product to satisfy the marketing programme.

7.63.3 *Related Techniques*

Maintenance Scheduling : Technique 63.

Marketing Management : Technique 57.

Queueing Theory : Technique 14.

7.64 Technique 66 — Failure Investigations [*see* Table 2, Phase (iv)(2)(a)]

7.64.1 *Basic Principles of Technique*

In the event of any failure in the asset, an investigation should be carried out at an appropriate level to identify the cause, if at all possible. The investigation may range from a formal committee of investigation consisting of experienced specialists for a serious failure to a simple report from the maintenance staff carrying out the repair of a minor failure.

7.64.2 *Usage in Terotechnology*

The majority of failures and thus investigations will take place in the operation and maintenance phase, but some failures may occur during commissioning. Although the primary target of an investigation is to identify the cause of failure, this is essentially the first step towards a consideration of whether there is a need to modify the asset itself or its operation or its maintenance. Finally, the results of investigations need to be fed back into the appraisal and assessment of future assets and projects.

7.64.3 *Related Techniques*

Fault Analysis : Technique 67.

7.65 Technique 67 — Fault Analysis [*see* Table 2, Phase (iv)(2)(a)]

7.65.1 *Basic Principles of Technique*

7.65.1.1 This technique relates to the identification of the source of a failure of an asset, as the first step towards its rectification. Diagnosis is initially dependent upon the report of operators as to the circumstances and symptoms manifest at the time of failure. Further information may be obtainable from tests carried out on the asset or part thereof. Some machines have sensors to detect specific abnormalities and some complex systems have installed computers to analyze such signals to deduce the failure source. Analysis is the process of considering all the information inputs to determine the root cause of failure.

7.65.1.2 This technique comprises a systematic analysis of the behaviour of the asset in the event of a fault of any feasible type in any component. Each study links a specific fault with its effects, manifestations and symptoms.

7.65.2 *Usage in Terotechnology*

This technique is used in the operation and maintenance phase.

7.65.3 *Related Techniques*

Failure Investigations : Technique 66.

7.66 Technique 68 — Tribology [*see* Table 2, Phase (iv)(2)(a)]

7.66.1 *Basic Principles of Technique*

Tribology is the study of the effects of relative motion of surfaces in contact and, in particular, into associated matters such as friction, lubrication and wear. It is therefore relevant in cases when the asset comprises or contains plant or machinery; it may also be of concern in structures where some relative movement, for example as a result of thermal expansion, can occur.

7.66.2 *Usage in Terotechnology*

In terotechnology, tribology aspects should first be considered at the design stage of the asset and thus during the acquisition phase. These aspects may, however, need to be reviewed either in the light of experience or as a result of developments in lubrication methods. Such reviews would be carried out during the operation and maintenance phase.

7.67 Technique 69 — Maintenance History and Analysis [*see* Table 2, Phase (iv)(2)(b)]

7.67.1 *Basic Principles of Technique*

7.67.1.1 The establishment and upkeep of maintenance records should be determined as part of the maintenance strategy. Apart from the need to establish records for administrative and managerial reasons, the maintenance records should be comprehensive and so arranged as to permit analysis to be carried out.

7.67.1.2 Such an analysis should be capable of providing data on frequency, duration of maintenance and causes or components.

7.67.2 *Usage in Terotechnology*

7.67.2.1 The maintenance history and its analysis for an asset are essentially carried out during the operational life of the asset. Results of the analysis are used to review the maintenance strategy of the asset, the need to consider modifications and to evaluate support strategies, such as spares holdings.

7.67.2.2 When new assets are contemplated, the maintenance history and analysis are used in evaluating investment proposals and in the acquisition phase to assist in judgements on the selection of assets, design requirements and maintenance strategies to be used with the new assets.

7.68 Technique 70 Repair/Replacement Optimization [*see* Table 2, Phase (iv)(2)(b)]

7.68.1 *Basic Principles of Technique*

7.68.1.1 In practice, when an asset is becoming worn, or fails, the option to replace the item rather than repair it often arises. A choice has to be made between these options.

7.68.1.2 A choice between repair and replacement should always be made on grounds of total economics of the complete asset rather than just the component concerned. In this case, one is concerned with the difference in cost between the two options but one also needs to take into account the values of differences in the required downtimes and future differences in costs of operation and maintenance. The future life and utilization of the asset can also be an influencing factor.

7.68.2 *Usage in Terotechnology*

The situation arises during the operation and maintenance phase, usually towards the end of the design life of the asset.

SECTION 3 CHECKLISTS

8 NINE CHECKLISTS ARE INCLUDED FOR USE BY DIFFERENT PERSONNEL IN THE ORGANIZATION

The checklists in **8.2.1** are intended to help organizations in the application of terotechnology. Each checklist is aimed at the personnel carrying out the function identified in its title. It also lists aspects that should be considered by this functionary, and either seeks confirmation that an aspect is already being adopted or questions whether it is practiced when appropriate and possible. Wherever an aspect is appropriate but not practiced in an organization, the checklist will highlight an area where improvements could be

8.1 Schedule of Checklists

The checklists given in **8.2** are intended for use by different personnel as follows:

Checklist No. 1. Overall management of a user organization

Checklist No. 2. Overall management of a supplier organization

Checklist No. 3. An organization's management accountants

Checklist No. 4. Personnel responsible or management of a new project

Checklist No. 5. Personnel responsible for purchasing new assets

Checklist No. 6. Personnel responsible for product design

Checklist No. 7. Personnel responsible for production (operation of assets)

Checklist No. 8. Personnel responsible for maintenance of assets

Checklist No. 9. Personnel responsible for marketing, sales or contracting for products made.

8.2 Checklists

8.2.1 *Terotechnology Checklist No. 1— For Overall Management of a User Organization*

a) *General*
  1) Ensure that there is effective two-way communication between the organization and the suppliers of plant, machinery, equipment, buildings, structures or other physical assets.
  2) Check that this includes quantitative information on the following:
    i) Functional utility;
    ii) Health and safety in all phases, including disposal;
    iii) Reliability;
    iv) Maintainability;
    v) Types (and man-hour costs) of malfunction or failure;

   - vi) Man-hour costs of maintenance (including overhaul and repair); and
   - vii) Environmental compatibility.
3) Ensure that there is an efficient system for monitoring, recording and analyzing the performance and life cycle costs of the physical assets used by the organization.
4) Are the following being considered :
   - i) Condition monitoring?
   - ii) Trends in quality and quantity of the output or service obtained from the unit in question?
   - iii) Trends in the costs of use and maintenance?
5) Encourage those responsible for purchasing to:
   - i) Maintain interest in the physical assets of the organization;
   - ii) Make a positive contribution to decisions affecting the acquisition; and
   - iii) Take full account of life cycle criteria when recommending or selecting a supplier of bought-in components or assemblies.
6) Check that manuals and other support literature:
   - i) Are acceptable to those in the organization who install, operate and maintain the units in their care; and
   - ii) Permit the preparation of life cycle plans, including financial provisioning.

b) *When making decision on acquisition of a new physical asset*

1) Ensure that the investment appraisal:
   - i) Is based on a life cycle plan;
   - ii) Has taken account of, and displays, the balance between initial cost and total life cycle costs;
   - iii) Compares the estimated life cycle costs and performance of the proposed acquisition with those of refurbishing and recommissioning units already in service; and
   - iv) Recognizes the full implications of quality assurance.
2) Before making or confirming the decision to acquire a new asset, consult the concerned persons responsible for:
   - i) Finance;
   - ii) Marketing;
   - iii) Production;
   - iv) Maintenance;
   - v) Quality; and
   - vi) Safety.
3) Ensure that the statement of your requirements:
   - i) Is unambiguous; and
   - ii) Covers all relevant aspects of life cycle performance.
4) Check that it will permit intending suppliers to:
   - i) Prepare without delay a specification for comment or agreement; or
   - ii) Submit proposals for modifications which they consider will make the asset feasible or more acceptable on grounds of performance or costs.
5) Ensure that proposals for modification are communicated to and acted upon without delay by those who will be responsible for installing, operating and maintaining the unit.
6) Ensure that the proposals for modifications made by the organization are kept to the necessary minimum and can be justified.
7) Check that the effects on cost and delivery of modifications to the asset in question are fully communicated.
8) Ensure that decisions on proposals for modification are communicated without delay to the potential supplier.
9) Review terms of warranties offered by intending suppliers when placing the order. Assess their potential value and take this into account in economic assessments.
10) Ensure that the purchasing specification has been agreed by all those who were consulted on acquisition of the unit in question.
11) Ensure that the purchasing specification includes adequate data on all aspects of life cycle performance.
12) Ask for confirmation of warranties, price and delivery.
13) Use the life cycle plan to monitor and record progress and costs starting from the time when acquisition was first considered.
14) Inform all concerned that changes in the purchasing specification after the order

is placed will be prevented.

15) Ensure that there is a formal procedure for dealing with proposals for modification which may result from:
    - i) Problems in design and manufacture or construction; and
    - ii) Unavoidable changes in requirements.

c) *After delivery*

1) Check that those who will be responsible for operating and maintaining the unit are satisfied with :
    - i) Its testing;
    - ii) Its installation;
    - iii) Availability of documents/manuals for operation and maintenance;
    - iv) Its performance; and
    - v) Their relationship with the supplier.
2) Ensure that all legal, regulatory and commercial formalities are completed correctly (for example those relating to safety and warranties).
3) Review how promises, estimates or forecasts of:
    - i) Functional performance;
    - ii) Spares;
    - iii) Reliability;
    - iv) Maintainability; and
    - v) Costs

    have been substantiated or modified between placing the order and acceptance of the unit.
4) Consult with those in the organization who are responsible for finance, marketing, production, maintenance, purchasing and quality on how this review will affect the organizations' future plans.

8.2.2 *Terotechnology Checklist No. 2. For Overall Management of a Supplier Organization*

a) *General*

1) Ensure that there is effective two-way communication between the organization and the users of plant, machinery, equipment, buildings and structures or other physical assets.
2) Check that this includes adequate data on the following:
    - i) Installation and commission;
    - ii) Health and safety in all phases, including disposal;
    - iii) Functional utility;
    - iv) Reliability;
    - v) Maintainability;
    - vi) Types (and man-hour costs) of malfunction or failure;
    - vii) Man-hour costs of maintenance (including overhaul and repair); and
    - viii) Environmental compatibility.
3) Ensure that information received is transferred to and acted upon without delay by those in the organization who are responsible for marketing, design and manufacture.
4) Encourage those responsible for marketing to base their strategy on the life cycle costs and performance of the products.
5) Ensure that manuals and other support literature:
    - i) Meet the needs of the customers; and
    - ii) Give adequate data on all aspects of life cycle performance, including availability of spares and the estimated man-hour costs of overhaul and repair.

b) *When initiating a new product or responding to an enquiry*

1) Consult with those in the organization who are responsible for finance, marketing, design, manufacture and quality when:
    - i) Specifications and tenders are being prepared or modified;
    - ii) Costs are being estimated and prices fixed; and
    - iii) Warranties are being considered.
2) Check that the potential user's statement of requirements:
    - i) Is unambiguous;
    - ii) Covers all relevant aspects of life cycle performance; and
    - iii) Permits either the immediate preparation of a specification or tender, or effective and speedy discussion of details which need resolution and agreement.
3) Check that the specification:
    - i) Enables reasonably accurate estimates of the time and cost of design and manufacture from those responsible; and
    - ii) Permits firm statement of price and

delivery date of the product in question.

c) *After the order has been placed*

1) Ensure that modifications to the specification are minimized.
2) Ensure that changes to the specification:
    i) Asked for by customer; or
    ii) Identified as essential because of changes in the market for the product; or
    iii) Arising from problems in design which cannot be resolved by other means;

    are communicated to all those concerned and acted upon appropriately and without delay.
3) Check that adequate records are kept of modifications and of their estimated effects on cost and deliver.
4) Ensure that all concerned, including the purchaser, are properly informed of these.
5) Check that no processes or materials are introduced unless or until their effects on life cycle performance have been taken fully into account.

d) *During manufacture or construction*

1) Ensure that modifications are kept to the absolute minimum.
2) Ensure that requests for modifications are arising from changes in customer requirements, changes in the market or problems in production, are acted upon with all possible speed and, if agreed, implemented with the minimum disruption to the manufacturing programme.
3) Make sure that the reliability and maintainability of the unit is checked against forecasts.
4) Check that the design is cost effective, that it is the most economic means of meeting the specification, particularly in respect of life cycle costs and performance.
5) Ensure that all functions within the organization are collaborating to make it so.
6) Check that there is rapid and continuous feedback from manufacture or construction to design and finance on difficulties in fabrication or assembly and on aspects of design which affect maintainability.
7) Ensure that those responsible for quality pay particular attention to relevant aspects of life cycle performance of the unit, including vendor rating of potential suppliers, the scrutiny of specifications for outsourced items, and assessment of the items on receipt.

e) *After delivery*

1) Check that all legal, regulatory and commercial formalities have been completed correctly (for example those relating to safety and warranties).
2) Check that the user is satisfied with the following:
    i) Performance of the product including installation;
    ii) Performance of the organization (supplier); and
    iii) Information supplied on use and maintenance.
3) Review how forecasts of :
    i) Functional performance;
    ii) Spares;
    iii) Costs;
    iv) Reliability; and
    v) Maintainability.

have been substantiated or modified during:

- i) Design;
- ii) Manufacture;
- iii) Installation and commissioning; and
- iv) Early use.

4) Check that appropriate actions have been taken by all concerned.
5) Consult with those responsible in the organization for Marketing, Design and Production on how the review will affect future plans.

For Checklist No. 3 to Checklist No. 9, the panel authorized the secretariat to make necessary modifications and as far as possible to change the text from first person to third person.

8.2.3 *Terotechnology Checklist No. 3—For Management Accountants*

a) *General*

1) Is positive contribution done towards the management of physical assets used by the organization?
2) Is data collected any analyzed on asset performance and reliability and on operating and maintenance costs?

3) Do life cycle costs form part of the investment appraisal and planning process for new acquisitions by your organization?
4) Is the information needed to prepare life cycle cost estimates available?
5) Does this include data from :
    i) Manufactures *via* the purchasing department?
    ii) The maintenance department; in order to compare the effects of different levels and types of maintenance?
    iii) Production and marketing; to assess the effects of manning and reliability on production costs and on deliveries to customers?
    iv) Stores; to assess the level and costs of spares holdings experience of other users?
6) Are forecast life cycle costs updated and used as the basis for subsequent monitoring and control of performance of the asset?
7) Is it possible to identify the costs of poor reliability of production or service plant, for example quantify the costs of capital tied up in standby or non-productive plant and equipment?
8) Is it possible to identify the direct and indirect costs of degradation in performance of plant and equipment used for the production of goods or services, that is the costs associated with a defective asset?
9) Is it possible to identify the costs of the separate parts of the life cycle and the differential and opportunity costs of trade-offs between them?
10) Able to update capital cost to current values to enable present costs to be prepared on a meaningful basis?
11) Are the cost of the following in relation to particular assets, or groups of assets known:
    i) Design (for plant designed in-house)?
    ii) Installation?
    iii) Commissioning and run-up?
    iv) Training of operative and maintenance personnel?
    v) Unreliability (that is the direct and indirect costs of down-time)?
    vi) Maintenance (costs broken down into the various types of maintenance used within the organization?
    vii) Spares holdings?
    viii) Disposal?

b) *Investment appraisal*
    1) Contribute to the financial appraisal before a decision is taken to scrap an old asset or purchase a new one?
    2) Check that the management who are responsible for decisions on asset acquisition understand the full costs and implications of the various options presented to them.
    3) Check that the data used in the investment appraisal represent all significant costs.
    4) Are the costs of the various options shown together with the effects of different levels of reliability (and hence different levels of down-time)?
    5) Check that the appraisal is based on a realistic life of the asset.
    6) Is the cost of ownership calculated over the full expected life of the asset and not just over the 'pay-back period'?
    7) How sensitive are the resulting figures to variations in particular costs (for example would a 10 per cent increase in maintenance costs plus 5 per cent extra down-time make the purchase uneconomic)?
    8) Access to reliable data on all the items to be included in the investment appraisal is there?
    9) Is account of inflation and of the timing of cash flows taken?
    10) If not, is this because your costing and recording system is unsatisfactory?

Is it ensured that data collection and computer services are compatible with company requirements?

8.2.4 *Terotechnology Checklist No. 4— For Personnel Responsible for Management of a New Project*

a) Ensure that a clear statement of the organization's objectives for the new project, including all health and safety considerations is available.

b) Ensure that all possible schemes for meeting the objectives are identified.

Then for all possible schemes:

a) Establish process flow diagrams indicating flows of feed materials, products, by-products and waste and a material balance sheet if appropriate.

b) Establish outline specifications describing significant features of the required assets, the processes and operational and control requirements.

c) Identify any stocking requirements for feed materials, inter-process stocks and finished products.

d) Identify significant environmental parameters and all requirements for the treatment and disposal of effluents, waste products, gaseous discharges and all forms of energy emissions, and disposal of the asset itself. In addition draw up a description of the visual quality of the environment and establish any special needs for preservation or treatment.

e) Develop mechanical flow diagrams to show the types of plant or equipment to be installed and the most economic way of handling materials onto, through and off the site.

f) Develop mechanical flow diagrams to show the types of plant or equipment to be installed and the most economic way of handling materials onto, through and off the site.

g) Develop general layout proposals, taking into account requirements for optimizing operations, associated stock areas and maintenance activities as well as providing for all necessary pedestrian and vehicular access needs.

h) Review the asset schedule against best known practices preferably on a worldwide basis.

j) Estimate asset cost and time required to design, manufacture, deliver and install all components.

k) Identify all services required for the asset.

m) Draw up a services balance sheet for each service showing rates of usage, and quantities lost and re-circulated on both an average and a peak rate basis.

n) Check the availability of services and compare this with the requirements of the proposal.

p) Identify any needs and costs of providing additional services, and any additions to the asset schedule which may be necessary.

q) After consultation, establish target availabilities for the asset and its major components, taking into account:

    1) Target outputs of the product;
    2) Capacity of the asset;
    3) Needs for maintenance; and
    4) Expected down-time for breakdowns.

r) Identify manpower requirements for operation, maintenance and administration and patterns of work to be adopted.

s) Identify needs for recruitment and training of staff.

t) Identify administration requirements such as weighing facilities, clocking stations and changing facilities, first aid, fire protection and security facilities, and offices.

u) Identify additional assets, costs and time needed to provide requirements outlined in (r), (s) and (t).

v) Identify workshop facilities and all buildings needed to provide requirements outlined in (r), (s) and (t).

w) Establish economic appraisals for each scheme considered, identifying initial and life cycle costs and potential returns and compare with objectives.

x) Obtain approval for the selected or recommended scheme.

Then proceed on the basis of the approved scheme only as follows:

a) Prepare a detailed layout drawing, this being a block plan of all buildings, spaces, plant, stockyards, roads, railways, etc, for the site on which the asset is to be established.

b) Initiate surveys of the site including any necessary geo-physical surveys and surveys of existing buildings to be utilized in the project.

c) Draw up a contracts schedule to show how components of the required asset can be grouped suitably for contract purposes. Denote the types of contract intended for each group and establish clear interfaces between contracts.

d) Identify potential suppliers, carry out vendor assessments and establish approved tender lists.

e) After due consultation with all affected parties, finance, purchasing, product design, production and maintenance, draw up specifications for components and issue enquiries to potential suppliers on approved tender lists.

f) Receive tenders and carry out comparative assessments of offers taking into account differences in performance and life cycle costs.

g) On the basis of assessments select suppliers to be awarded contracts for supply of components to constitute the asset.

h) Establish a master programme for the asset design and supply based on network or cascade analysis of the whole project, including commissioning and work-up to target performance levels.

j) On the basis of the master programme, draw up the following:

   1) An expenditure programme for each contract;
   2) An individual programme for each contract;
   3) A progress monitoring system;
   4) A project team organization showing staff requirements, needs for consultants etc;
   5) A site layout plan and a plan for the construction and/or erection stages; and
   6) Quality assurance plans.

k) Agree a full schedule and programme for acceptance tests to be applied to principal components.

8.2.5 *Terotechnology Checklist No. 5— For Personnel Responsible for Purchasing New Assets*

a) *General*

   1) Is there effective two-way technical communication between the organization and those from whom you acquire plant, machinery, equipment, buildings, structures or other physical assets?
   2) Do the departments or functions within the organization that are concerned with a physical asset after purchase collaborate in preparation of the specification?
   3) Check that the company corporate plan makes financial provision for acquisition of the item in question.
   4) Check that the specification includes and/or demands adequate data on the relevant aspects of life cycle performance.
   5) Are there adequate statements of requirements for:
      i) Delivery, installation and commissioning (if appropriate)?
      ii) Functional performance?
      iii) Life?
      iv) Reliability?
      v) Maintainability?
      vi) User information?
      vii) Overhaul and repair manuals?
      viii) Health and safety and impact on the environment in which the asset will be used, and disposal?
   6) Is there adequate exchange of data with your suppliers on operating experience?

b) *When selecting a supplier*

   1) Check that the specification of the asset to be acquired is clear and unambiguous.
   2) Check that the specification covers all relevant aspects of life cycle performance.
   3) Will the specification enable intending suppliers to prepare realistic estimates for costs and delivery?
   4) Check that full details of any modifications to the specification proposed by intending suppliers have been given to the originators of the relevant part of the specification, and actioned, if necessary, by amendment and re-issue of the specification.
   5) Have intending suppliers proposed any trade-off between initial purchase price and estimated total life cycle costs, for example will payment of a higher price permit a significant reduction in total outgoings?
   6) Have intending suppliers provided adequate information on forecast costs and availability of service and/or critical spare parts during the expected life of the asset?

c) *Before placing an order*

   1) Check that the information provided by intending suppliers is adequate for making or confirming the decision to acquire the asset in question (that is, does it provide an adequate response to your enquiry?). This applies equally to custom built and to catalogued items.
   2) Check that the company corporate plan includes the life cycle of the asset, and makes financial provision for it.
   3) Check that the purchase specification is a clear and complete statement of your requirements.

4) Check that the supplier's conditions of sale are not at variance with your short and long-term requirements.
5) Check that the specification has been agreed by all those who will be concerned with:
    i) Installation;
    ii) Commissioning;
    iii) Operation;
    iv) Maintenance;
    v) Health and safety; and
    vi) Disposal.
6) Consult with the quality department manager or engineer on quality aspects of the specification?
7) Check the vendor ratings of the intending suppliers.
8) Check the intending supplier's warranties and forecasts of availability of service and critical spare parts.
9) Check that the quantity and quality of the information supplied with the asset will be adequate for operation, overhaul and repair during its expected life.

d) *After delivery*

1) Check that procedures and formalities concerned with acceptance of the asset have been completed corrected.
2) Check that satisfactory technical manuals, have been provided for the asset.

8.2.6 *Terotechnology Checklist No. 6— For Personnel Responsible for Product Design*

a) *General*

1) Is there effective two-way communication between the organization and those to whom it supplies your products?
2) Does it include feedback from users to you of quantitative data on:
    i) Costs of installation and commissioning?
    ii) Functional utility?
    iii) Maintainability?
    iv) Reliability?
    v) Types of failure or malfunction?
    vi) Costs of overhaul or repair?
    vii) Costs of failure or malfunction?
    viii) Safety and environmental compatibility?
3) Account of whole-life cycle costs when designing the company's products is taken?
4) Do you take part in decision on:
    i) Performance and price of a new product?
    ii) Preparation and presentation of tenders?
    iii) Preparation and presentation of technical information, for example manuals and brochures?
5) Is estimate done as to how decisions on the design of a product, both before and during design and development, will affect:
    i) Costs of design and manufacture?
    ii) Costs of installation and commissioning?
    iii) Costs of overhaul and repair?
6) Is there any feedback of information for this purpose from the company's manufacturing, construction and quality departments?
7) Is collaborate with the organization's marketing and sales personnel when considering aspects of design which can have a significant effect on whole-life performance and costs of the product done?
8) Does this include discussion of trade-offs between first cost and total life cycle costs of the product?
9) Is the information you supply adequate for:
    i) Installation, use and maintenance of the products you design?
    ii) Preparation of brochures and other literature describing their performance and competitive advantages?

b) *When initiating a new design or responding to an enquiry*

1) Check that a statement of requirements is available which will enable to:
    i) Prepare a specification or tender and give estimates of time and costs of design and development; and
    ii) Consult the company's manufacturing or construction departments on preferred processes and procedures; or
    iii) Propose modifications which will make the project feasible or the

product more acceptable to the organization or to the user.

2) Does the statement include adequate information on:
   i) Functional performance required?
   ii) Factors influencing life cycle costs?
3) Is proposed design based on past experience?
4) Does this include data on like or similar items, including:
   i) Acceptability to the user?
   ii) Health and safety and environmental compatibility?
   iii) Reliability?
   iv) Maintainability?
   v) Disposal?
5) Check that proposals for modifications to the specification have been considered and answered by the appropriate experts.
6) Are all those concerned informed of:
   i) Agreed modifications?
   ii) Issue number of the specification to which you are working?
   iii) Current estimates of time and costs of design and development?
7) Does this include the company's Marketing department?

c) *During design and development*

1) Check repeatedly that the specification to which you are working describes what is wanted.
2) Are all practical steps take to minimize:
   i) Changes in the specification?
   ii) Changes in the design?
3) Check that records are kept of proposals for modification to the specification or to the design, whether agreed or not.
4) Check that full and adequate records are kept of the assumptions that you have made in initiating and implementing the design.
5) Check that the customer, whether he be the intending purchaser or your company's Marketing department, is informed of how these assumptions will determine the characteristics of the product.
6) Check that the specifications and support literature for components and other bought-in units are compatible with the agreed design philosophy.
7) Check that the introduction of new materials, components or processes will not affect life cycle performance adversely.
8) Have adequate information on their:
   i) Durability (for example fatigue and weathering)?
   ii) Ease of fabrication (for example shaping and joining)?
   iii) Ease of repair?
9) Have the following been consulted:
   i) The company's Quality department or engineers?
   ii) Other designers?

d) *When releasing the design for manufacture or construction*

1) Check that all drawings and other documentation are in accordance with the agreed and latest issue of the specification.
2) Have estimates or forecasts of reliability and maintainability?
3) Has the potential user confirmed his acceptance of the specification?
4) Have those who will be responsible for manufacture or construction accepted the configuration and processes you propose?
5) Check that all modifications made to the specification or to the design have been formally agreed and recorded.
6) Check that the requirements of quality assurance management are formally agreed and recorded.
7) Check that full and adequate records of design assumptions and important calculations (for example on stress and fatigue, life of rubbing and rolling surfaces, corrosion and weathering) are in a form suitable for retention for the expected life of the item concerned.
8) Check that there is adequate information for the preparation of manuals and other documents on installation, use and care of the item concerned.
9) Does this include data on:
   i) Site and services requirements?
   ii) Installation and commissioning?
   iii) Operation?
   iv) Health and safety?
   v) Overhaul and repair?
   vi) Recalibration?

- vii) Spares?
- viii) Environmental compatibility?
- ix) Computer compatibility?
- x) Disposal?

10) Have you operated the item yourself or observed others operating it?

11) Have potential users and maintainers expressed their opinions on the acceptability of your design?

12) Did the user's comments result in improvements?

8.2.7 *Terotechnology Checklist No. 7— For Personnel Responsible for Production (Operation of Assets)*

a) *General*

1) Is there effective two-way communication between your organization and those from whom it acquires plant, machinery, equipment, buildings, structures or other physical assets?

2) Does this include exchange of information on:
- i) Functional utility?
- ii) Reliability?
- iii) Maintainability?
- iv) Health and safety?
- v) Types and man-hour costs of failure or malfunction?
- vi) Man-hour costs of maintenance (including overhaul and repair)?
- vii) Environmental compatibility?

3) Participation in decisions affecting the acquisition of new physical assets is done?

4) Is it considered how production programmes and specifications of functional performance will affect:
- i) Availability?
- ii) Reliability?
- iii) Maintainability?
- iv) First costs?
- v) Total life cycle costs?

5) During the preparation of the specification for a new asset, is collaboration done with those in the organization who are responsible for:
- i) Finance?
- ii) Maintenance?
- iii) Quality?
- iv) Procurement?
- v) Project Management?

6) Does the organization have life cycle plans for the equipment and other physical assets which is used for the production of goods or services?

7) Is adequate information on all the costs of use and maintenance of the equipment received from accounts department?

8) Does this information include comparisons between forecast and actual costs?

9) Do the suppliers provide adequate manuals and other support literature on the physical assets acquired by your organization?

10) Does this include data on availability of spares and service for the expected life of the asset in question?

b) *When decisions are being made on acquisition of a new asset*

1) Check that the statement of requirements:
- i) Is unambiguous;
- ii) Covers all relevant aspects of life cycle performance.

2) Have those who will operate the asset, or have operated similar units have been consulted?

3) Check that the intending supplier will provide adequate information on:
- i) Installation;
- ii) Commissioning;
- iii) Use;
- iv) Health and safety;
- v) Reliability;
- vi) Maintenance (including overhaul and repair);
- vii) Spares;
- viii) Environmental compatibility; and
- ix) Disposal.

4) Check with those responsible for purchasing that proposals for modifications to the specification or for trade-off between first costs and total life cycle costs have been passed for comment.

c) *Before the order is placed*

1) Check that the specification defines what is require.

2) Check that information on site requirements for delivery, installation and commissioning will be received, in good time.

   3) Inform all those concerned that everything, possible will be done to ensure that proposals for modification to the specification are kept to a minimum.

d) *After delivery*

   1) Check that the unit meets the specification.
   2) Have consulted those in the organization who are responsible for:
      i) Quality?
      ii) Maintenance?
   3) Does this include information from those who will personally operate and maintain the unit?
   4) Check how forecasts of costs, performance and maintainability have been substantiated or modified between placing of the order and acceptance of the unit.
   5) Will proposed modifications affect your programme and are they acceptable in this light?
   6) Check that the life cycle plan and monitoring system is operating effectively for your purposes.

8.2.8 *Terotechnology Checklist No. 8— For Personnel Responsible for Maintenance of Assets*

a) *General*

   1) Is there effective two-way communication between your department and others, for example, Production, Accounts and Purchasing etc?
   2) An appropriate maintenance strategy has been evolved ?
   3) Does this include a fault recording and analyzing system which provides information on:
      i) Availability?
      ii) Reliability?
      iii) Maintainability?
      iv) Costs?
      v) Health and safety?
   4) Do production programmes take account of information provided on maintenance schedules?
   5) Is participation done in decisions affecting the scrapping of old or the acquisition of new physical assets?
   6) Aware of the total cost of maintenance, that is, the direct cost (actually doing the work) and the indirect costs (including overheads and the consequential costs of lost production)?
   7) Is information on direct and indirect costs of maintenance fed back to top management, not necessarily at their initiative?
   8) Has it been discussed with colleagues in accounts and production whether a recording system for both direct and indirect maintenance costs would be beneficial in assessing the right time for equipment replacement?
   9) Is encouragement given to consider all aspects of the life cycle of physical assets acquired by the company, or expected to stick to maintenance? (Maintenance is only a part, albeit an important one, of an asset's lifecycle.)
   10) Is feedback information given to the suppliers on unreliability and difficulties in maintenance of the units they sell or manufacture?
   11) Is maintenance considered to be:
      i) An essential part of production or manufacturing; or
      ii) Merely a 'service to production'?
   12) Does the management consider maintenance to be:
      i) An essential part of production or manufacturing; or
      ii) An activity which does not contribute to profitability?

b) *Before purchase of an asset*

   1) Are the cost implications of the decisions considered?
   2) Is participation done in the preparation of the specification for a new physical asset before the order is placed?
   3) Does the specification include adequate information on:
      i) Health and safety?
      ii) Reliability?
      iii) Maintainability?
      iv) Environmental compatibility?
      v) Disposal?
   4) Is the supplier required to provide information on design assumptions made by his designer?
   5) Check that the supplier is required to provide data on reliability and maintainability.
   6) Check that the supplier is required to

provide adequate and effective technical information, in the form of manuals or by some other means, on the use and maintenance of the asset.

7) Is participation done in evaluation of the intending supplier's proposal for supply of a physical asset?
8) Does this evaluation include life cycle costs?
9) Check whether the type and level of maintenance recommended by the supplier is appropriate to your needs.

c) *When an asset is in service*

1) Check that the forecast reliability and maintainability figures are achieved in practice.
2) Check that the supplier has provided technical manuals and other supporting information in accordance with your specification.
3) Have elements of 'condition based' maintenance into the strategy as an alternative to routine or scheduled action introduced?
4) Are monitoring trends in product quality useful in assessing equipment condition?
5) Are model techniques made use for:
    i) Diagnosis of faults?
    ii) Determining their cause?
6) Check that the required level of availability (and no more than that) is being achieved at an economic maintenance cost.
7) Could the maintenance load be reduced without impairing either immediate availability or long-term asset care?
8) Are discussions done with colleagues in manufacturing the requirements for availability and the costs of providing it?
9) Have a suitable recording and analysis routine for failures and preventative maintenance of the asset been established?
10) Have data from the recording and analysis system to optimize the maintenance strategy or propose modifications are used?

8.2.9 *Terotechnology Checklist No. 9— For Personnel Responsible for Marketing, Sales, or Contracting for Products*

a) *General*

1) Is there effective two-way technical communication between your organization and those to whom it supplies your products?
2) Market or sell on the basis of life cycle performance?
3) Assist those in the organization responsible for product design to give full consideration to those aspects of design which can have a major effect on a product's whole-life costs?
4) Does this include feedback of quantitative data from users on:
    i) Installation and commissioning?
    ii) Functional utility?
    iii) Reliability?
    iv) Maintainability?
    v) Costs of failure or malfunction?
    vi) Costs of maintenance (including overhaul and repair)?
    vii) Health and safety and environmental compatibility?
    viii) Disposal?
5) Collaborate with other departments or functions in the organization when:
    i) Specifying the performance and price of a new product?
    ii) Responding to an invitation to tender?
6) Do these departments or functions include:
    i) Product design/engineering?
    ii) Production?
    iii) Quality?
    iv) Finance?
7) Does this collaboration include discussion of data on:
    i) Site and services requirements?
    ii) Operations?
    iii) Health and safety and environmental compatibility?
    iv) Overhaul and repair?
    v) Recalibration?
    vi) Spares?
    vii) Other requirements for product support?
    viii) Disposal?

b) *When responding to an enquiry*

1) Check that the prospective purchaser's specification will permit to prepare valid estimates of delivery and price.
2) Has the specification been considered by

   the departments or functions in the organization who will be concerned with implementing the order?
   3) Have they made any proposals for trade-offs between first cost, performance and whole-life costs?
   4) Check that modifications to the specification proposed by the organization have been considered by the prospective customer, and answered.
   5) Check that working is done on the latest issue of the purchase specification.
   6) Check that the potential customer has all the information required for making and confirming his decision to acquire the product in question; this applies equally to catalogue and to custom built items.
   7) Does this proposal bring out clearly the important competitive features of the product and options or trade-offs between first cost and total life cycle costs?
   8) Check that it includes adequate data on:
      i) Installation and commissioning (if necessary);
      ii) Performance and operation;
      iii) Health and safety;
      iv) Reliability and maintainability;
      v) Availability of spares and service for the forecast life of the unit;
      vi) Environmental compatibility; and
      vii) Disposal.

c) *Before accepting an order*
   1) Check that the specification accompanying the order is acceptable to all departments and functions in the organization who will be responsible for working to it. Are they agreed that it meets the purchaser's declared requirements for quality and fitness for purpose?
   2) Have any reservations regarding the specification been expressed by:
      i) Engineering/design.
      ii) Manufacture/construction?
      iii) Quality?
      iv) Finance?
   3) If so, have these been resolved by agreement with the prospective purchaser?
   4) Check that there is an agreed procedure for handling all aspects of changes in the specification which may become necessary during design, construction, installation or commissioning.
   5) Are there discrepancies between the organization's standard warranties and conditions of sale and those asked for by the prospective customer?

d) *After deliver*
   1) Check that procedures and formalities concerned with acceptance of the item have been completed correctly.
   2) Check that the customer is satisfied with the item and with the information supplied on its operation, care and maintenance.
   3) Check that information on failures, reliability, maintainability, and health and safety can and will be fed back from the user and acted on by your organization.

ANNEX A

(*Clause* 2)

LIST OF REFERRED INDIAN STANDARDS

IS No.	*Title*
397	Method for statistical quality control during production:
(Part 0) : 2003	Guidelines for selection of control charts (*first revision*)
(Part 1) : 1972	Control charts for variables (*first revision*)
(Part 2) : 2003	Control charts for attributes (*third revision*)
(Part 3) : 2003	Special control charts by variables (*first revision*)
(Part 4) : 1987	Master control systems
6363 : 1997	Glossary of terms in work study (*first revision*)
7200	Presentation of statistical data:
(Part 1) : 1989	Tabulation and summarization (*second revision*)
(Part 2) : 1975	Statistical quality control (*second revision*)
7373 : 1985	Glossary of terms in project network analysis (*first revision*)
IS/ISO 9000 : 2000	Quality management systems — Fundamentals and vocabulary (*second revision*)
IS/ISO 9001 : 2000	Quality management systems — Requirements (*second revision*)
IS/ISO 9004 : 2000	Quality management systems — Guidelines for performance improvements (*fifth revision*)
9990 : 1998	Glossary of terms in terotechnology (*first revision*)
11810 : 2003	Guidelines to establish a value engineering activity (*first revision*)
12040 : 1987	Guidelines for development of supplier rating system (*first revision*)
13407	Techniques of work study:
(Part 1) : 1992	Method study
(Part 2) : 1995	Work measurement
14001 : 1994	Quality systems — Model for quality assurance in design, development, production, installation and servicing
14580 (Part 1) : 1998	Use of network analysis for project management: Part 1 Management, planning, review, reporting and termination procedures
15001 : 2000	Occupational health and safety management systems — Specification with guidance for use

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